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Brownell

Wisconsin Railroad Comm. [illegible]

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1

REPORT

ON

The Electric Street Railways of Milwaukee, Wisconsin

AND

OTHER PUBLIC UTILITY COMPANIES

FOR THE

CITY OF MILWAUKEE

WITH

HISTORICAL REFERENCES ON STREET RAILWAYS AND ELECTROLYSIS

TOGETHER WITH REPORT ON

A REPORT MADE BY THE NATIONAL BUREAU OF STANDARDS, NOVEMBER 26, 1918

OF

ELECTROLYTIC CONDITIONS IN MILWAUKEE

FOR

RAILROAD COMMISSION OF WISCONSIN

BY

E. E. BROWNELL, B. E. E.

JUNE 1, 1920

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Contents

Pages
Preface 9-12

PART I

Brief historical and statistical record of the Milwaukee Water Works 13-20

PART II

Electricity and direct current distribution in electric street railway practice 21-70

PART III

Early and late modes of direct current distribution applicable to electric street railways 71-80

PART IV

Electrical distribution systems of the Milwaukee electric street railways 81-91

PART V

Statistics before and after electrification of the Milwaukee street railways 92-96

PART VI

Electrolytic conditions in the City of Milwaukee, Wisconsin. (Brief resumé) 97-115

PART VII

Various electrolytic surveys on Milwaukee Water Works. (Brief recital) 116-125

PART VIII

Bibliography of parties conducting electrolytic surveys and mitigations. (Including authors of technical literature) .. 126-192

PART IX

Various diagrams of systems of electrolytic mitigation....... 194-206

PART X

The Wisconsin Railroad Commission, its duties and jurisdiction 207
The Wisconsin Railroad Commission in the Beloit, Wisconsin, electrolysis case 207-215

PART XI

The interurban street railways of Milwaukee, Wisconsin..... 216-218

PART XII

Pages
Litigation on electrolytic deterioration of water, gas and telephone systems 219-230

PART XIII

American Telephone and Telegraph Company, commonly known as Bell Telephone Company of United States and Canada (Electrical interference between telephone companies and street railways)..............................231-248

PART XIV

Comments of E. E. Brownell on testimony of G. W. Van Derzee before the Railroad Commission of Wisconsin, in Milwaukee, Wisconsin, June 13, 1918........................249-252

PART XV

An Act creating the National Bureau of Standards and its activities in electrolysis investigations and mitigations and its annual appropriation.............................253-288

PART XVI

Resolution authorizing litigation and proceedings of Common Council and City Attorney against The Milwaukee Electric Railway and Light Company, the reports of the Committee on Water-Works Sewerage to Common Council, February, 1918, and tentative report of March 27, 1919, to Wisconsin Railroad Commission 289-316

PART XVII

Comment (E. E. Brownell) on report made by the National Bureau of Standards in November, 1918, for Railroad Commission of Wisconsin, relating to electrolytic conditions in the City of Milwaukee (with recommendations and conclusions) 317-330

INDEX

Covering 301 persons mentioned in the 17 parts and 330 pages of the report 331-337

PART XVIII

Interlocutory Court Order—Milwaukee County Circuit Court, February 11, 1920....................................339-341

PART XIX

Railroad Commission of Wisconsin report..................343-350

PART XX

Testimony of Burton McCollum, correspondence to and from National Bureau of Standards and conclusions of E. E. Brownell 351-358

ILLUSTRATIONS

Facing Page
1. George H. Benzenberg. Portrait about 1890............... 16
2. Front view North Point Pumping Station.................. 18
3. Thomas Alva Edison. Portrait about 1892................. 22
4. Thomas A. Edison's first electric locomotive in 1880......... 24
5. Thomas A. Edison's improved electric locomotive in 1882... 25
6. Daft electric street railway, Baltimore, Md., August, 1885... 26
7. Electric street railway statistics of the world. May, 1887..... 26
8. Short double trolley system in 1889 27
9. Dr. Edward Weston. Portrait about 1888................. 28
10. Charles J. Van Depoele. Portrait about 1890............... 30
11. A tram car in New York City. About 60 years ago......... 36
12. Siemens and Halske electric railroad in Berlin, Germany, 1879 37
13. First electric railway in Paris, 1881, with overhead wire..... 38
14. Double trolley system in Asbury Park, N. J., in 1887........ 39
15. Horse car days in America from 1870 to 1890............... 42
16. Mansfield, Ohio, double trolley system in 1887.............. 42
17. Early inventors' portraits and pioneer railway engineers..... 44
18. Copper table prices 1860-1917 inclusive 54
19. Electric railways using direct current in excess of 650 volts.. 74
20. First electric street railway powerhouse in Milwaukee in 1889 86
21. Milwaukee street railway track system in November, 1892... 88
22. Milwaukee conflagration of October 28, 1892. Showing map 92
23. Burning of the old Kinnickinnic barns, December 28, 1892... 94
24. Electrolyzed lead service water pipe in Milwaukee about 1893 96
25. Rail-to-Pipe connection map of old mitigating system in 1893 98
26. First electrolyzed cast-iron water main in Milwaukee. In 1893 100
27. First electrolyzed cast-iron water main on East Side. In 1898 101
28. First photograph electrolyzed lead service pipe in U. S. (1892) 102
29. Electrolyzed c. i. water main. Milwaukee, June, 1919....... 104
30. Electrolyzed c. i. water main. Milwaukee, Nov. 20, 1919..... 110
31. Electrolyzed c. i. water main. Milwaukee, Nov. 28, 1919..... 111
32. Electrolytic chart of Milwaukee in 1900 by E. E. Brownell... 116
33. Electrolytic chart of Milwaukee in 1915 by Frank K. Brainard 118
34. Wooden insulated joints in water main. Brookline, Mass.... 142
35. Electrolytic chart of Beloit, Wis., of August 21, 1917......... 208
36. Electrolytic chart of Beloit, Wis., of April 20, 1919.......... 210
37. Electrolytic mitigating system cables (Beloit, Wis., 1919)... 212
38. Electrolytic chart of Altoona, Penna., June 20, 1919......... 270

DIAGRAMS AND TABLES

Pages

1. Brooklyn, N. Y., street railways data from 1854 to 1901... 25
2. Street railways of United States in cities over 100,000 pop. 28
3. West End Street Railway Company of Boston, Mass., from 1889 to 1894 30
4. Electric street railways in America, October, 1889........ 31-35
5. Thomson-Houston electric railways, April, 1890......... 45
6. Sprague electric railways, April, 1890 46
7. United States Government report of 1890 on street railways 48-54
8. Massachusetts street railway report of 1892.............. 56-57
9. Canadian cities report per capita in 1893 57
10. American street railway systems for small cities 59
11. Wage scale in Ohio for street railway employees in 1892.. 60
12. Electric street railways in United States in 1898.......... 64-68
13. Electric street railways in United States in 1907.......... 69
14. Electric street railway statistics in 22 cities in 1917....... 70
15. Earth plates of an electric street railway system in 1892... 84
16. History of rapid transit in Milwaukee in 1893............ 90-91
17. Title page to Boston report of 1893 by City Engineer.....106
18. Boston, Mass., voltage chart on water mains, January, 1894 113-114
19. D. C. Jackson's patent for electrical pipe continuity......129
20. Authors on electrolytic surveys and mitigations..........149-156
21. Title page of International Electric Congress, St. Louis, 1904 180
22. Municipal reports on electrolysis, ordinances, etc., 1903...189-193
23. Mitigation diagrams (11) by E. E. Brownell.............196-206
24. Bell Telephone diagram 1876 to 1918. Showing installations 247
25. Wisconsin Telephone Company statement 1891 to 1918...248
26. National Bureau of Standards. Annual appropriation....283-284

PREFACE.

In writing, as well as compiling, the following exhaustive report, the writer had in mind nine (9) important purposes. To make clear these purposes, it has been found highly essential to lay particular stress upon the historic features of the Milwaukee Water Works, the street railway companies and the telephone company of the City of Milwaukee.

The prime consideration is to get a complete record of certain public utility conditions, that has taken place in years gone by, in the City of Milwaukee, before it is too late to obtain one. For those who are here today, familiar with the many important features of this interesting subject, may not be with us tomorrow.

It may appear that considerable portion of the information and references given are quite unnecessary; but to the interested party and the student of the subject, there will be found unlimited food for good thought in and between the lines of this detail report, giving as it does all of the available data upon the subject.

It is sincerely hoped that the citizens of the City of Milwaukee will profit by reading it, and that the efforts of the writer, as the Consulting Electrical Engineer for the City of Milwaukee, will not be found wholly without merit.

In the faithful performance of one's moral and ethical duty, in defending the sovereign and inalienable rights of a municipality, where unwarranted hatred and malice are shown by the public service corporation in maintaining its unprincipled position, it ofttimes becomes imperative to safeguard the municipality with all the force that honest methods and equitable proceedings will permit.

Many public utility companies believe it to be good management to exploit their selfish interests irrespective of the rights and privileges of the public. Furthermore, the moment an engineer represents a municipality, no matter upon what subject, that he is either a rogue, or a fool or both, in the eyes of the unscrupulous public utility company.

There is no higher ethical engineering duty, than to represent and protect the public interests.

The following are the nine valuable purposes to be achieved in writing this report, namely:

1. A brief history of the Milwaukee Water Works from the original date of construction to the present day. The high type of its official management, and of those who made it such a complete and remunerative system of water works. Its fine character of construction and operation, and why it must be preserved for future generations, against unnecessary and willful electrolytic corrosion, as caused by the electric street railway companies of the City of Milwaukee.

2. Early electric street railway practice, throughout the United States, with special reference being made to the original and present day practice in the City of Milwaukee. Showing that even in 1889 this question of operation was seriously considered by the City of Milwaukee, as to the proper method to be employed.

3. Electrolytic conditions in the City of Milwaukee, as affecting the Milwaukee Water Works system; together with various early reports and records in Milwaukee and additional reports, made by other engineers, including the writer's electrolytic investigations, beginning in 1893 and ending in 1919; also many citations and references on the subject, as applying directly and indirectly to the City of Milwaukee.

4. The bibliography of those engaged in conducting electrolytic surveys and electrolytic mitigations, including the years from 1888 to 1919, with brief descriptions.

5. The various court cases on the rights of injunction, for injury to and the destruction of subsurface metallic structures by electrolytic deterioration, with comments that are comprehensive to a layman upon the subject of electrolysis.

6. A brief history of the parent company of the Wisconsin Telephone Company (American Telephone and Telegraph Company), and its peculiar position throughout the United States, as well as in the City of Milwaukee, on the electrolysis question.

7. Giving the public access to the information gained from many years' actual experience of the writer with the hope that such data may be of some value, to other municipalities and owners of sub-

surface metallic structures, in similar controversies where they are the sufferers.

8. In a sincere effort to guide his client, the City of Milwaukee, in the proper handling of this important subject, for the future good of the City of Milwaukee, and at the same time without undue hardship upon the electric street railway companies.

Owing to the nature of this present controversy, it is deemed very judicious, though much to the regret of the writer, to omit considerable valuable and exhaustive research work along this particular line, which the technical world should have by all means. It is readily apparent that, at this time, it would seriously jeopardize the best interests of the City of Milwaukee to set forth such technical information to be used by an unscrupulous company. It is quite obvious that nothing short of litigation will properly judicate this serious and menacing evil, and relieve the City of Milwaukee of further destructiveness from electrolytic action.

9. The immediate necessity for writing and compiling this report, together with all the various early articles bearing upon the subject of "Electrolytic Deterioration" in the City of Milwaukee, with citations and references, embodied in, or attached to this report, has been forced forth in defense of the City of Milwaukee, because of a written report made by the National Bureau of Standards of Washington, D. C., dated November 26, 1918, and amended on June 7, 1919, for the Railroad Commission of the State of Wisconsin.

The electrolytic survey and report upon the electrolytic conditions of the City of Milwaukee was made by the National Bureau of Standards, for the Railroad Commission of the State of Wisconsin in 1918, after the City Councils of Milwaukee had officially voted 28 to 6 against them coming into the City of Milwaukee—yet they came notwithstanding under the apparent disguise of the State of Wisconsin, through the Railroad Commission.

In other words, The Milwaukee Electric Railway and Light Company, in early 1918, refusing to arbitrate or negotiate with the representatives of the City of Milwaukee, were instrumental in getting the Railroad Commission of Wisconsin to call in the National Bureau of Standards to make the electrolytic survey upon the Milwaukee Water Works system.

For the time being, it was indeed, a very clever move on the part of this electric street railway company, for it aimed to get the sovereign power of the State of Wisconsin to compel the City of Milwaukee to adopt such a system and policy as would have divested the City of Milwaukee of all of its municipal rights and privileges, moral, legal and equitable, as relating to electrolytic depreciation from diverted electrical currents.

This report, made under the auspices of the National Bureau of Standards in 1918, showing certain electrolytic conditions in the City of Milwaukee, contains many theoretical and impractical suggestions and recommendations.

In the opinion of the writer, the report is a very partisan one in stating views with respect to the operation of The Milwaukee Electric Railway and Light Company. The effect being to belittle the seriousness of electrolytic corrosion upon the distributing piping system of the Milwaukee Water Works.

This report is the apparent work of theorists, and in the writer's opinion is full of untrue and unwarranted statements. These statements, as given, are of no real benefit to the complaining public, and still less to the engineering fraternity. They do not arrive at any one specific conclusion without modifications galore.

Therefore, the writer will attempt to show the many reasons why such a report could not be made appliable to the best good and interest of the Milwaukee Water Works. So far as an "Electrolysis Committee" is concerned, acting for the various public utilities of Milwaukee, including the City of Milwaukee, it is pitiful to imagine the ineffectiveness of such an organization, as the National Bureau of Standards would perfect on the electrolysis question.

The field of the professional consulting electrical engineer should be the one to look to, as the proper method of handling this important subject.

The writer wishes to acknowledge the hearty support given him by the McGraw-Hill Book Company of New York, N. Y., in making direct quotations from their various technical journals. For this the writer is professionally indebted to them.

On his own professional staff, the writer wishes to extend to his associates Messrs. Robert E. Fritsch, H. Hesselbacher, John L. Locher and Paul R. Brown, his sincere appreciation for their loyal and cooperative services.

E. E. BROWNELL.

Philadelphia, Penna., September 1, 1919.

PART I

REPORT TO THE CITY OF MILWAUKEE, WISCONSIN

Philadelphia, Penna., September 1, 1919.

PERCY BRAMAN, Deputy Commissioner of Public Works,
and
H. P. BOHMANN, Superintendent, Water Works and Water Purification, City of Milwaukee, Milwaukee, Wisconsin.

Gentlemen: I herewith present to you, as the chief executive and the operating head of the Milwaukee Water Works system, my full and complete report upon the Electrolytic Conditions in the City of Milwaukee, Wisconsin; together with the various important angles of this vital subject matter, so that the proper comprehensive conception of the subject may be thoroughly reviewed and consistently treated as a whole.

The Milwaukee Water Works distributing system, owned and operated by the municipality, is the main sufferer from electrolytic action of all of the subsurface metallic structures in the City of Milwaukee, and probably more seriously affected than all other, privately owned, subsurface metallic structures combined in the City of Milwaukee.

It has, therefore, been considered opportune to recite a brief history of the Milwaukee Water Works, as taken from various viewpoints, before getting into the subject of Electrolysis.

The return current diversion, due to the operation of The Milwaukee Electric Railway and Light Company, the Milwaukee Northern Railway Company and the Chicago, North Shore and Milwaukee Railroad Company, in the City of Milwaukee, will be treated hereinafter in detail.

BRIEF HISTORICAL AND STATISTICAL RECORD OF THE MILWAUKEE WATER WORKS

The history of the Milwaukee Water Works dates back to the year of 1871, when the Legislature of the State of Wisconsin, on March 24, 1871, approved an Act "To enable the City of Milwaukee to construct Water Works and carry on and manage same." The Board of Water Commissioners, created by this Act, and under whose management the Water Works were built, had the exclusive charge and management of the same until July 1, 1875, at which time in accordance with the provisions of the City Charter, the control and management were surrendered to the Board of Public Works.

From the laying of the first cast-iron, lead-calked water main to the present date of June, 1919, makes the Milwaukee Water Works distributing system 47 years old this month.

The following is a quotation from the original records, beginning with the creation of the first Board of Water Commissioners:

"In pursuance of the provisions of Sections One and Two of Chapter 475 of the Private and Local Laws of 1871, the Board of Water Commissioners met at the office of the Mayor, for the purpose of determining, by lot, their respective terms of office.

"On motion of John Plankinton, Edward O'Neill was elected chairman pro tem, and on motion of E. H. Brodhead, Guido Pfister was elected Secretary pro tem.

"The Chair appointed John Plankinton to draw the names, which resulted as follows:

"For term of 1 year —George Burnham.
For term of 2 years—Edward H. Brodhead.
For term of 3 years—Guido Pfister.
For term of 4 years—John Plankinton.
For term of 5 years—Alexander Mitchell.
For term of 6 years—Frederick Pabst.
For term of 7 years—Edward O'Neill."

The above names constituted the full quota of the Milwaukee Water Commissioners, which, by law, was fixed at seven. The Act which created the Milwaukee Board of Water Commissioners was passed by the Wisconsin Legislature on March 24, 1871. The Board of Public Works consisted of three commissioners and the City Engineer, who, by reason of his position was ex-officio President of the Board of Public Works.

April 19, 1910, the three-member Board of Public Works was abolished and a one-man commission established, pursuant to the provisions of Chapter 279, laws of 1907.

The date of the first meeting of the Board of Water Commissioners was on April 18, 1871.

On May 8, 1872, the first bids were opened for laying the first cast-iron water mains in the City of Milwaukee.

On June 12, 1872, the actual laying of the water mains was begun. They began on Broadway at Buffalo Street and continued northward therefrom. The water main was of 6-inch, lead-calked, class "B," cast-iron bell and spigot, tar-coated construction.

All water service pipes were of the standard lead type.

On November 3, 1873, the first water was turned into the Milwaukee Water Works distributing system.

The first and only water works pumping station was at the foot of North Avenue on Lake Michigan.

During the year of 1872, there was laid about 13 miles of cast-iron water main. All lead-calked with lead service pipes.

Mr. Thomas McMillan was the construction engineer for the steam engine contractors of E. P. Allis & Co. from the time the engines were contracted for until they were turned over to the City of Milwaukee, completed and duly accepted, and has continued in the capacity of Chief Engineer from the time the engines first started up to the present day for the Milwaukee Water Works.

This unbrokn record of Mr. McMillan, serving for 47 years, beginning from the day that the first engine was started, is a most remarkable record (1872 to 1919), which probably can not be surpassed in the practice of water works operation in the United States today, especially when considering the longevity of service and a high class municipal operator of a public utility requiring unlimited practical skill and technical knowledge. A great advantage to the City of Milwaukee.

On July 1, 1875, in accordance with the provisions of the city charter the Milwaukee Water Works was placed under the direct jurisdiction of the Board of Public Works.

Under this new city charter, the City Engineer was ex officio the President out of a total of three Commissioners.

The following are the City Engineers who served the City of Milwaukee, beginning 7 years before the introduction of electric traction in Milwaukee and continuing up to the present date.

George H. Benzenberg, February 6, 1882, to April 18, 1899.
Charles J. Poetsch, April 18, 1899, to April 11, 1911.
Joseph A. Mesiroff, April 11, 1911, to April 21, 1914.
George Staal, April 21, 1914, to present date.

It is therefore self-evident, that Mr. George H. Benzenberg, who being technically well versed, acquired readily the requisite knowledge necessary for the successful installation and maintenance of Milwaukee Water Works and was the guidingi factor, not only during his 17 years' (1882-1899) service as City Engineer, but as the technical adviser for many years following his resignation as City Engineer. Mr. Benzenberg lived through a period of rapid progression in all public utility works, an opportunity which he did not let pass without availing himself of its fullest extent.

Mr. Benzenberg was City Engineer for seven years prior to the changing of mule power to electric traction and for the first ten years of electric traction in the City of Milwaukee. This made him most intimately acquainted with original construction, operation and maintenance of the Milwaukee electric street railway companies during which time electric street railways were making history.

No other city official of the City of Milwaukee, Wisconsin, is so intimately connected with all of its municipal utilities and so thoroughly versed in the public service corporations, as Mr. Benzenberg.

The standard water works system was adopted and not only standard pumping equipment and intake methods employed, but invariably improved upon through the genius and untiring efforts of Mr. Benzenberg. His master hands can be seen in many other public improvements in the City of Milwaukee today.

The citizens of the City of Milwaukee, Wisconsin, owe Mr. Ben-

G. H. Benzenberg

About 1890

zenberg a debt which they will never be able to pay him for his unlimited value in guiding the City of Milwaukee along the proper source to pursue in its public improvements. His great achievements are about all of a subsurface nature of which the public know so little, and therefore so little appreciated, but those who have followed his career feel it impossible to express their high admiration and respect.

The Milwaukee Electric Railway and Light Company can never assail the Milwaukee Water Works, as contributing to electrolytic deterioration, through carelss pipe line construction or improper maintenance of the distributing water works system in the streets of the City of Milwaukee. Neither will they ever be able to prove one single instance where faulty materials and construction have ever contributed to the menacing evil of electrolysis within the City of Milwaukee, even to an infinitesimal degree. A valuable practical and legal asset to the City of Milwaukee.

The present water works distributing system is as standard construction today as it was in 1873. the date it was originally started

The Milwaukee Water Works is known throughout the United States, as the very highest type of economical and efficient management of a public utility. It has few equals, either privately or municipally operated, in this most valuable public utility

The whole distributing system of the Milwaukee Water Works consists of tar-coated, bell and spigot, lead-calked cast-iron water mains with lead service pipes.

Mr. Henry P. Bohmann has served well the City of Milwaukee being in the Department of Public Works from [illegible] to [illegible] and [illegible] then in the Water Department, the last 8 years as Superintendent

Therefore, let us make no mistake in handling the [illegible] matter, so as to conform with the efficient operation of the Milwaukee Water Works.

PRESENT STATISTICS

Up to January 1, 1919, the Milwaukee Water Works [illegible] the following construction and operation

A total of 542.9 miles of lead-calked cast-iron, water [illegible]

A total of 65,721 consumers, both private and industrial.

Pumping capacity rated normally at 118,000,000 gallons for 24-hour service with a maximum rated capacity of 125,000,000 gallons per day of 24 hours.

Average water pressure about 40 pounds per square inch.

Range in water pressure from a minimum of 20 to a maximum of 90 pounds per square inch.

About 46.9 per cent of the total water pumped is delivered to the high level district.

All water service pipes up to one and one-half (1½) inch are of lead construction. All above 1½-inch are cast-iron.

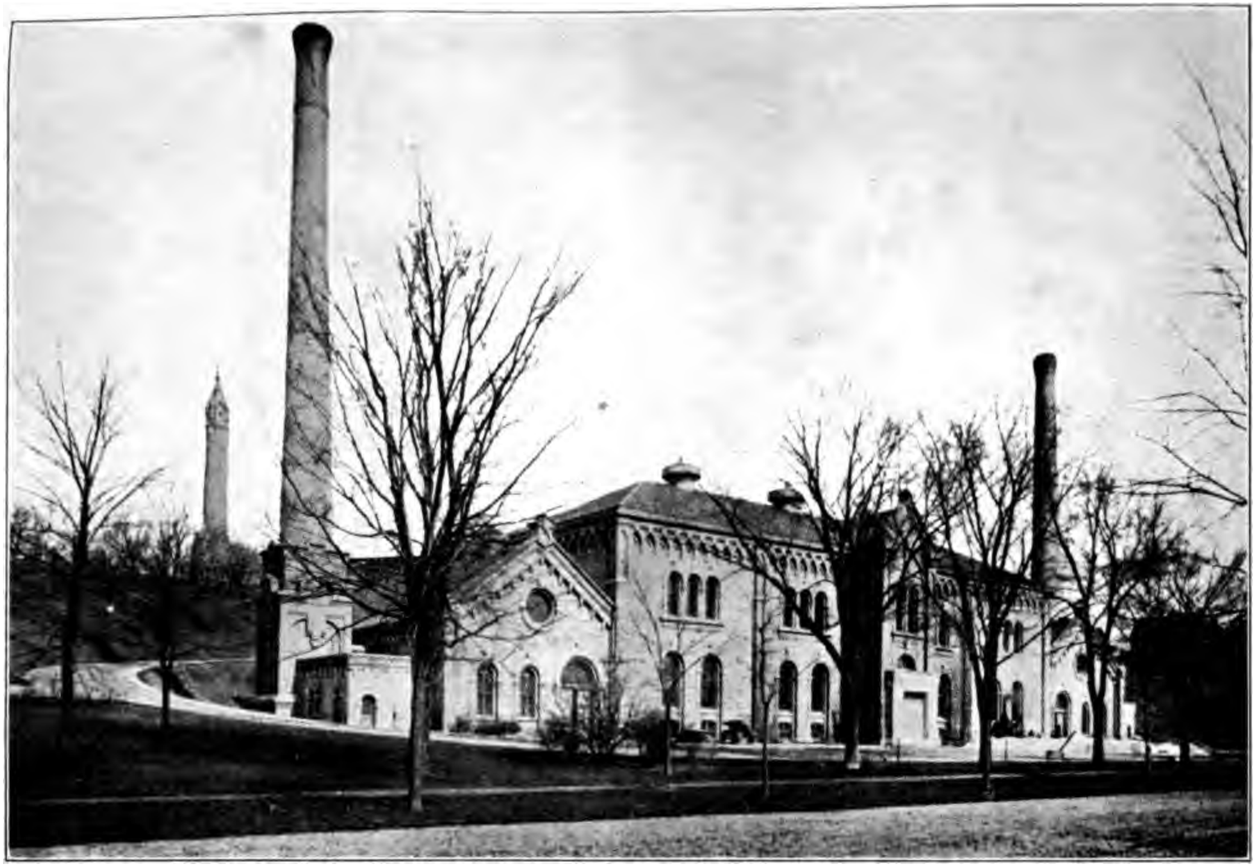
Up to January 1, 1919, the City of Milwaukee had invested the sum of $5,042,566.57 in the actual cost of the Milwaukee Water Works distributing system, practically all of which occupies the streets of the city.

To replace this most valuable and essential water works distributing system, now largely covered up under costly paving, together with the high cost of lead and cast-iron and high-priced labor and sundry materials with 65,721 service connections to change, it would cost close to the sum of Fifteen Million ($15,000,000) Dollars, say nothing about the hazard of interrupted service, trouble and annoyance. Had no electrolytic deterioration ever attacked this valuable property, it would continue to perform all the requirements and service, for which it was originally intended for many hundreds of years. There is no limit yet ascertained, as to the life of cast-iron and lead pipe construction buried in ordinary virgin soil throughout the United States of America.

A few years ago there was taken from the River Seine, Paris. France, a cast-iron pipe which was laid in 1802. This cast-iron showed no appreciable evidence of deterioration. The maker's name and the date cast on each length were easily read.

In Rheims, France, some cast-iron pipes were taken up in 1840, that were laid in 1748, and reports state that the cast-iron was as good as when laid.

A standard water works system is, by far, the most indispensable and necessary public service utility. The health, protection and com-



FRONT VIEW NORTH POINT PUMPING STATION
MILWAUKEE, WIS.

(Reprinted by E. F. Brownell)

for of the entire community depend solely upon it, for this utility has no substitute in a large city.

The operation of the Milwaukee Water Works Department is for the best good of all the public and is not a dividend-paying, public service corporation. Every living person in the City of Milwaukee has a direct interest in preservation of this property.

MILWAUKEE WATER WORKS BOND ISSUE

(Engineering News and Contract Journal, March 1, 1884, Page 105)

Milwaukee, Wis., February 26, 1884. A big kick is being raised by eastern capitalists because the city proposes to call in 5% of the water bonds issued between the years 1872 and 1874. The total issue was $1,600,000.00. The first bonds of the issue were called in last year, the amount redeemed being $76,000.00 leaving $1,524,000.00 still outstanding.

It is now proposed, in compliance with law, to call in a like proportion of the bonds on the first of next June, 1885.

Many of the bondholders maintain that as no right is reserved in any of the bonds to redeem prior to the year of 1902, none of the bonds can be redeemed before that time. The bonds are drawing interest at the rate of 6½% and 7%. A large number of the bonds are held in Boston, and the holders propose to contest the right of the City to redeem them and a big suit may follow.

MILWAUKEE WATER WORKS

(Engineering News, October 25, 1890, Page 366)

Milwaukee is noted among American cities for not having introduced a general public water supply until 1873, when her population must have been upwards of 80,000. This is all the more striking when we consider that for a western city Milwaukee has been settled many years, there having been a population there of 712 in 1840, 20,061 in 1850 and 71,440 in 1870, about the same time that the construction of the works was begun.

The supply introduced in 1873 was taken from Lake Michigan, at a point 2,100 feet from the pumping well on the shore, 36-inch intake pipe extending into 18 feet of water at ordinary low level.

At present Allis pumping engines with a daily capacity of 30,000,000 gallons force water to a 21,000,000 reservoir, and a standpipe 4 feet in diameter by 130 feet in height.

PIPE FOR MILWAUKEE WATER WORKS

(Engineering News and Contract Journal, January 2, 1886, Page 13)

Milwaukee, Wis., December, 1885. On account of the upward tendency of the price of iron, the water works committee of the Milwaukee Common Council has decided to recommend the purchase of 5,000 tons of cast iron water pipe at a cost of over $100,000.00. The pipe will be needed in the Spring.

ANNUAL REPORT OF THE MILWAUKEE WATER WORKS

For the Year Ending December 31, 1912

(As it appears on page 23 of this report, which is the first mention made of electrolytic deterioration in any annual report.)

ELECTROLYSIS

On October 24th, 1910, the Common Council directed the City Attorney to begin an action against the Milwaukee Electric Railway and Light Company for damages sustained to the city water mains by stray electrical street railway current. Evidence of electrolytic corrosion has been found by the Distribution Department on a number of occasions and was found to be the cause of a number of leaks in our water mains. A partial survey was made by Mr. Ray Palmer of the Bureau of Efficiency and Economy and as a result of this survey sufficient evidence of damage by electrolysis was gathered to warrant a complete survey. In order to locate the danger area and to determine the amount of damage sustained in the past, I would recommend that a thorough survey be made of the entire distribution system. If this is done steps can be taken to prevent further damage from this source and the City Attorney be furnished with the necessary data to form the basis for the suit of damage which he was directed to start by the Common Council.

PART II

ELECTRICITY AND DIRECT CURRENT DISTRIBUTION IN ELECTRIC STREET RAILWAY PRACTICE

A BRIEF HISTORY

The discovery of electric currents originated with Galvani, a physician of Bologna, in or about the year of 1786. Galvani with the assistance of Professor Volta of the University of Pavia, first proved that the contact of two dissimilar metals produced opposite kinds of electricity upon the two surfaces, one being electrified positive and the other negative.

Next came the Voltaic cell, consisting of two dissimilar metals placed in a solution containing certain chemicals (electrolytes) with metallic wires leading from each. These wires when joined produced a "Direct Current" of electricity. Then came the battery, or a collection of galvanic cells, so as to procure a larger flow of current, than could be obtained from one cell.

The Voltaic cell was until 1831, the original and only source of direct or continuous current. The fundamental principle of the present storage battery.

In the Fall of 1831, Faraday discovered the magneto-electric induction of electrical currents. This new principle brought out the dynamo-electric machinery, used for converting mechanical power into the form of electrical energy, or vice versa, the electric motor, all date from the year of 1831.

Then followed a period of about 40 years, during which time great efforts were put forth to perfect the dynamo-electric machinery into practical operation.

In 1870, Gramme conceived the principle of winding a continuous coil in separate symmetrical sections around a ring, or other figure of revolution. He was followed by Bertin in 1875, Brush in 1879 (an American) and Siemens in 1880 on the principle of shunt winding.

The open coil machines were introduced in 1880 by Elihu Thomson and E. J. Houston, of Philadelphia, Penna.

In 1880 Weston devised several forms of dynamos of the shunt-wound type.

Now comes our great American, Thomas Alva Edison, born in Milan, Ohio, on February 11, 1847, but now at Menlo Park, New Jersey. In 1878 Mr. Edison built a dynamo in which the armature was oscillatory instead of rotary. This device was tried in 1856 by Dujardin and abandoned by him; also by Siemens in 1859 and by Wilde in 1861. Mr. Edison himself abandoned it in 1879, for a modified Hefner-Alteneck armature and an elongated shunt-wound electro-magnet.

In 1881 Mr. Edison produced a disk dynamo along the same lines as Pacinotto in 1878.

Edison's work perfecting dynamo-electric machinery in the early days was quite extensive. In the latter days he drifted away from it to more intricate and complicated apparatus.

THE DIRECT CURRENT ELECTRIC MOTOR

In September, 1821, Faraday established the principle of electro-magnetic rotation. He was assisted by Barlow in 1823.

The earliest electric motors, in which the principle of attraction by an electro-magnet was applied, were made by Henry in 1831, Dal Negro in 1832, Ritchie in 1833, Jacobi in 1834, Davenport in 1837, Page in 1838, Davidson in 1838, Wheatstone in 1841, Froment in 1857 and Pacinotti in 1865.

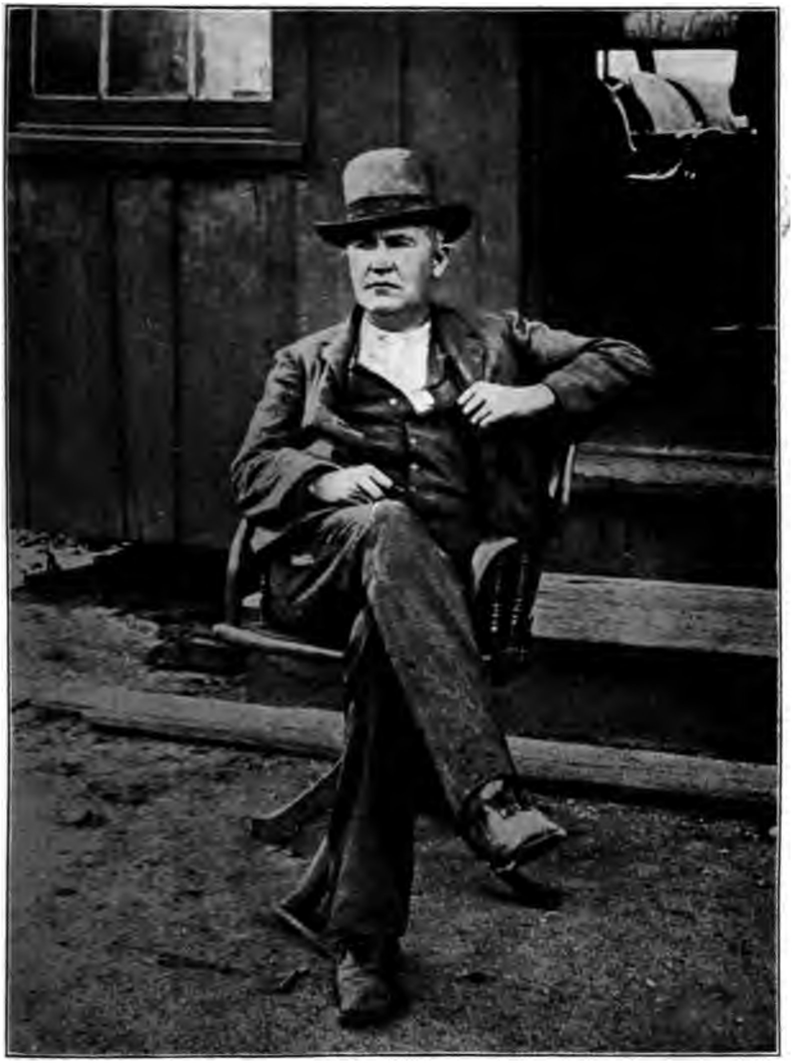
The discovery that the action of a dynamo is the simple converse of the electric motor, was made by Jacobi in 1850; although it did not become public until 1852. Walenn verified this in 1860 and Pacinotti in 1864.

Fontaine and Gramme made the first practical use of this principle at Vienna in 1873, the first public demonstration of a motor and dynamo working as one or the other. (Exhibition purposes only.)

Marcel Deprez made commercial use of the same in 1881.

Ayrton and Perry, in 1882, discovered the automatic regulation of motors by which they could be run with constant velocity.

The original date of Mr. Edison's electric locomotive at Menlo Park, New Jersey, May 13, 1880, was about the time of the birth of the American Electric Street Railway industry, even though in a very primitive stage.



THOMAS ALVA EDISON
(About 1892)

(Reprinted by E. E. Br
(September 1, 19

From the Laboratory
of
Thomas A. Edison,
Orange, N.J. Sept. 8,1919.

Mr. E. E. Brownell,
1418 Walnut Street,
Philadelphia, Pa.

Dear Sir:-

Your letter of August 26th is before me on returning from my vacation. I take pleasure in sending you herewith a print of the photograph of Mr. Edison taken in the 90's, as requested by you.

You are at liberty to use this picture in the report you mention, and I think it would be well for you to give credit to "Edison: His Life and Inventions" by Harper & Bros.

Yours very truly,

Wm H Meadowcroft

Assistant to Mr. Edison.

It was a 110 volt, direct current circuit, with one of the tram rails a Positive electrical conductor and the other one a Negative electrical conductor. The dynamos were two (2) twelve (12) horsepower "Longwaisted Mary Anns," each generating a current flow of 75 amperes.

Hering, Fritsche and Arnold in 1889 published many interesting technical articles upon armature windings of considerable value.

THE COMMERCIAL ELECTRIC STREET RAILWAY

The Lichterfelde-Berlin, Germany, line was first placed in actual operation, as an electric passenger street railway, in 1881.

It was 1.5 miles long and had two (2) electric motor cars, yet it carried over 100,000 persons in 1881. The dynamos were steam driven. This was a 160 volt circuit at the time. (See list of electric street railways of the world for 1887, indexed under "Illustrations," of this report.)

Cleveland, Ohio, in 1884, really opened the first commercial electric street railway that gave assurance of the ultimate success of the electric street railway of America.

The Frank J. Sprague system (single trolley) installed in Richmond, Virginia, beginning operation in February, 1888, was the first real electric street railway system in the United States, run for profitable purposes of investment, upon the streets of an American city of any size.

The Sprague system was installed upon The West End Street Railway, in Boston, Mass., and the first car ran on Monday, October 10, 1887, which a few years after became the greatest electric street railway system in the entire world of its day. They were five (5) years completing the electrification. (See page 58 of the "Compilation Section" of this report for complete historical record of Boston's first electric car.)

Baltimore, Md., Montgomery, Ala., Port Huron, Mich., Windsor, Canada, Detroit, Mich., Appleton, Wis., Denver, Colo., Scranton, Penna., Orange, N. J., and Los Angeles, Cal., all had electric street railways before Richmond, Va., but they were less in size and other important considerations.

FIRST AMERICAN ELECTRIC STREET RAILWAY.

CLEVELAND, O., October 8th, 1884.

E. C. PETERS, ESQ., *Chairman, Committee on Electricity as a Motive Power of the American Street Railway Association.*

DEAR SIR:—Your favor of the 30th ult. is at hand, and contents noted.

The electric railway which we are now operating here is about one mile in length, and at present only one car is run on it. The second car will soon be completed, and the line will then be extended across the railway-tracks to a distance of about one and a-half miles. This section, with its two cars, will be operated all winter without intermission, to demonstrate the "rough and ready" character of the motor, after which the system will be extended over the 20 miles of tramway owned by the East Cleveland Co.

Last winter we operated a trial railway, built in the yard of these works; and as it stood the tests of all kinds of weather, we have no doubt in our own minds as to its efficiency the year round.

Briefly the system may be described as follows:

Midway between the rails a conduit 8 inches deep is laid flush with the pavement, in the manner of a cable road. Two iron rails serving as conductors are supported within this conduit, and through a slot five-eighths of an inch wide in the top of the conduit a plow depends from the car, and by means of two brushes makes contact with the conductors. Through this plow the current is conveyed to the motor, which is situated between the wheels under the car, and is tightly boxed up to prevent access of dust, etc. The motor weighs half a ton, and the car is an ordinary two-horse box car, weighing, exclusive of motor, two tons. The motor is geared to the axles of the car by friction gear and link-belts. The movement is controlled by levers at either end of the car, these levers operating the commutator brushes on the motor to start, stop, or reverse the motor, or to make it go at any speed desired. It has been run at a speed of fifteen miles an hour.

The dynamo supplying the current is located about a mile from the line and is run by the engine used by the company for grinding corn. It is connected to the conductors in the conduit by an over-head line of No. 8 wire. In practice, no over-head line will be used and a greater economy may be anticipated. The power is sufficient to run two cars, as the engine and dynamo after being started in the morning, runs all day without attention. Only one man is employed to do the firing, and the expense of power, including fireman, coal and oil is about four dollars per day.

With a larger plant, larger and more economical engines, boilers and dynamos would be used, and a much greater economy obtained.

The conduit will cost from five to seven thousand dollars a mile when made of steel, and it ought to last a lifetime. To equip an ordinary two horse car will cost in the neighborhood of $1,500 and the power at the central station for each such car will be in the neighborhood of $1,200. Each car will pull another car of the same size.

The steepest grade we have experimented with is 500 feet to the mile, and no difficulty was found in overcoming it.

The conduit is kept free from dirt, snow, etc., by a brush depending from the car through the slot. Catch basins are placed at intervals varying from 50 to 100 feet, and where possible a sewer connection is made.

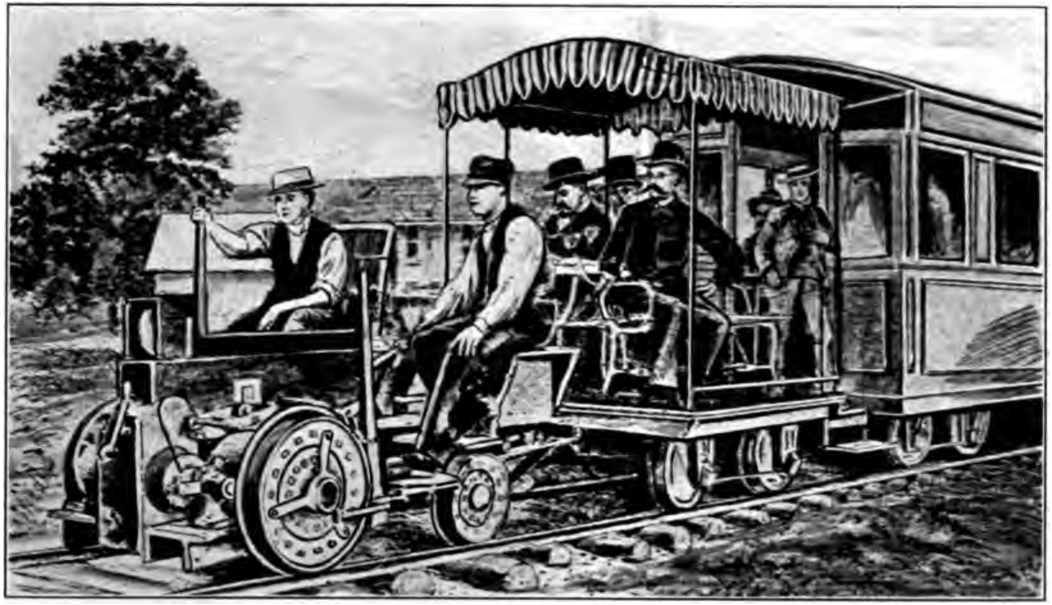
The system is similar to a cable road in that it requires a conduit and a central power station; but it differs in every other respect.

It may be operated on single tracks, as well as on double tracks; and branches may run out from the main road in every conceivable manner. Any speed may be assumed at the will of the operator without wear of machinery. Ordinary car-drivers can operate it after five minutes instruction. Stoppages can be made quickly by reversing the motor. Running off the track does not injure the machinery, and a flexible connection on every car enables the motor to run the car back on to the track when the lever is reversed. A much smaller conduit can be used than with cables, and there is no machinery along the line. The conductors cost but $200 a mile and the wear of the brushes upon them seems to be nil.

We use a high tension current because our investigations have showed us that when distances greater than one or two miles are to be overcome, no other current will give the necessary economy. The conductors are, however, inaccessible, and no danger is anticipated. We are ready to equip any road not exceeding 25 miles in length.

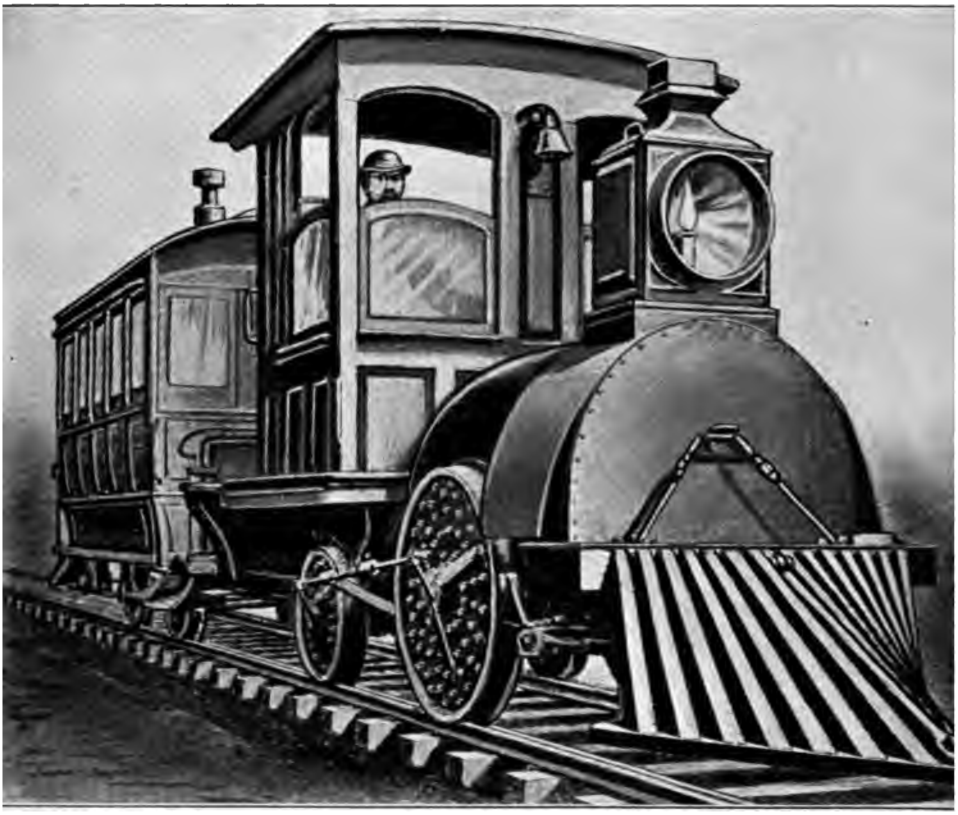
Hoping I have touched upon the main points of interest.

I am, very truly yours,
W. H. KNIGHT.



Thomas A. Edison's first electric locomotive in 1880. Positive and negatve rail with 20 volts between them.

(Copyrighted 1911, by McGraw-Hill Book Company, New York, N. Y.)



Thomas A. Edison's improved electric locomotive in 1882. Positive and negative rail with 220 volts between them.

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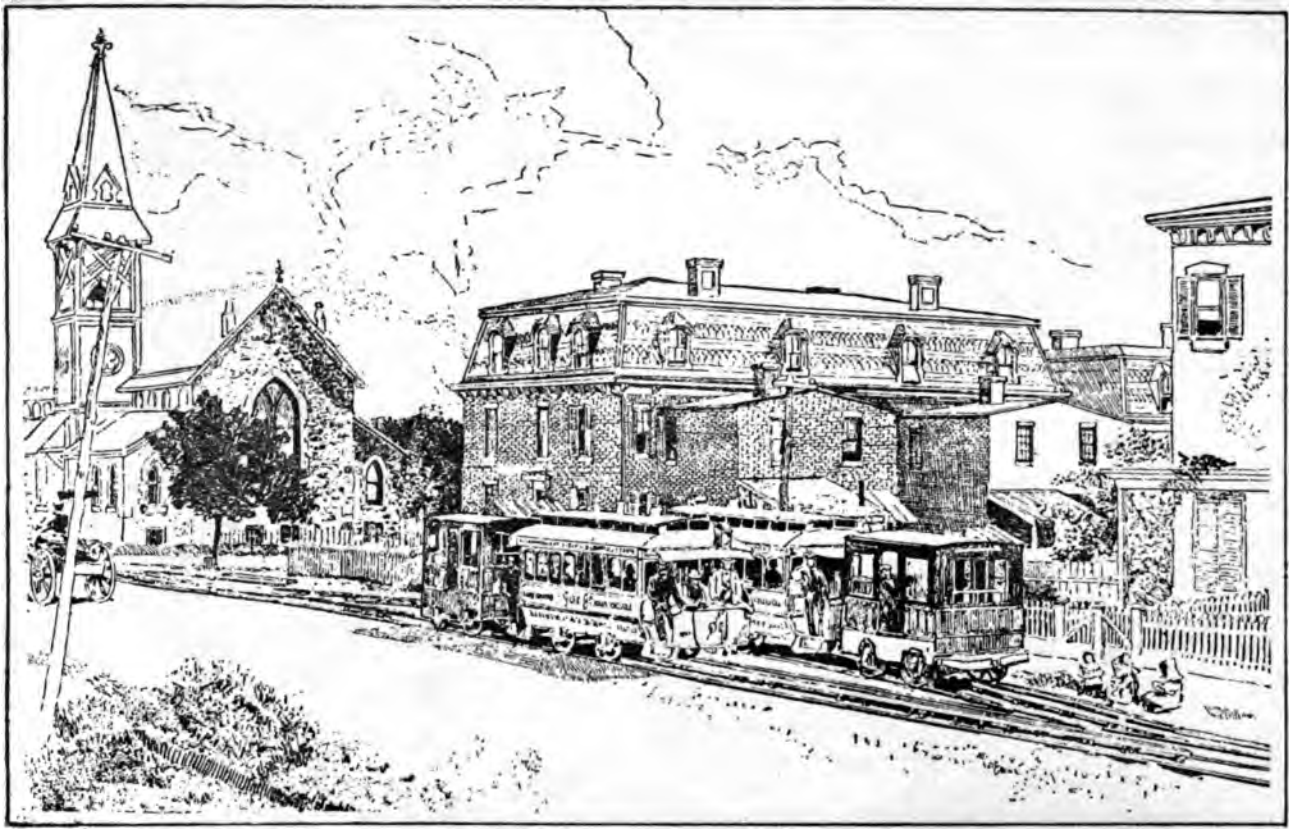
TABLE SHOWING POPULATION, MILES OF TRACK ON MAIN LINES AND NUMBER OF PASSENGERS CARRIED IN BROOKLYN, N. Y.

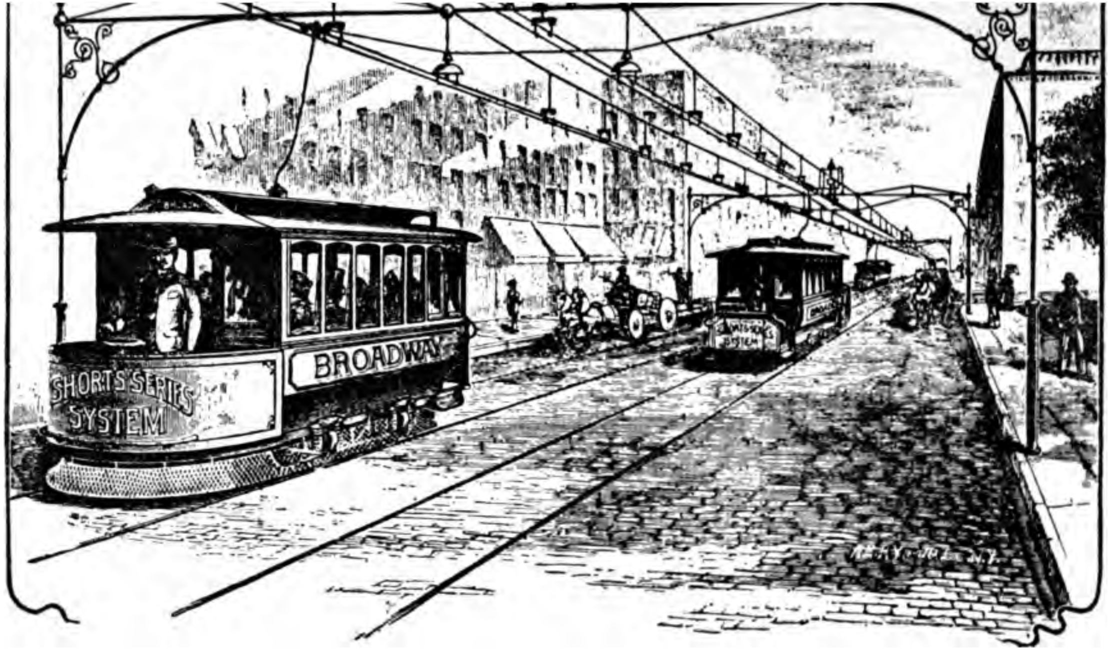
YEAR	Population	Miles of Track Main Lines		Passengers Carried						Remarks
		Surface (Double Track)	Elevated (Structure)	Surface	Elevated	Total	Increase			
							Surface	Elevated	Total	
1854	......	......	......	....	....	....	....	....	....	First surface cars operated in Brooklyn
1858	......	......	......	7,705,839	....	7,705,839	....	....	....	
1860	265,000	47.00	......	11,828,009	....	11,828,009	8,622,270	....	....	
1870	396,000	100.00	......	36,431,695	....	36,431,695	25,103,686	....	....	221 % increase in 10 years
1880	599,495	142,395	......	75,000,000	....	75,000,000	38,568,305	....	....	106 % " " "
1881	......	143.27	......	79,933,913	....	79,933,913	4,933,918	....	....	
1882	......	152.645	......	86,789,688	....	86,789,688	6,855,775	....	....	
1883	......	158.048	......	93,287,969	....	93,287,969	6,498,281	....	....	
1884	631,383	159.385	......	102 256,548	....	102,256,548	8,968,579	....	....	Brooklyn Bridge opened
1885	710,000	155.904	6.05	103,959,052	4,447,667	108,406,719	1,702,504	4,447,667	6,150,171	May 14, Brooklyn Elevated opened
1886	745,100	145.719	6.75	108,555,448	10,158,665	118,714,113	4,596,396	10,307,398	14,908,794	
1887	774,870	133.802	6.75	111,501,852	12,172,353	123 674,205	2,946,404	2,013,688	4,960,092	
1888	805,885	138.725	16.002	108,152,409	18,332,174	126,484,583	—3,349,443	6,159,821	2,810,378	April 24, K. C. Elevated opened
1889	820,000	139.845	23.048	106,874,365	34,127,359	141,001,724	—1,278,044	15,795,185	14,517,141	
1890	838,547	168.409	24.822	117,830,098	45,007,410	162,837,508	10,955,733	10,880,051	21,835,784	117 % increase in 10 years
1891	995,276	162.580	24.822	115,261,992	50,417,563	165,679,555	—2,568,106	5,400,153	2.832,047	
1892	1,000,000	158.595	24.433	122,518,186	53,353,769	175,871,955	7,256,194	2,936,206	10,192,400	
1893	1,020,000	165.452	27.912	137,715,699	56,654 409	194,370,108	15,197,513	3,300,640	18,498,153	Motive power began to be changed to electricity
1894	1,080,000	163.571	27.608	138,259,976	48,705,847	186,965,823	544,277	—7,948,562	—7,404,285	Motive power nearly all changed to electricity by end of year
1895	1,100,000	163.724	28.408	153,420,474	53,251,922	206,672,396	15,160,498	4,546,075	19,706,573	Year of trolley strike
1896	1,113,000	203.184	28.408	172,115,126	50,400,820	222,515,946	19,916,809	—2,851,102	17,065,707	
1897	1,126,000	213.915	31.821	200,139,500	45,684,379	245,823,879	28,024,374	—4,716,441	23,307,933	
1898	1,139,100	237.973	31.911	217,278,119	44,170,810	261 448,929	17,138,619	—1,513,569	15,625,050	Jan. 23, trolley cars first crossed bridge. June 18, elevated first crossed
1899	1,152,000	238.603	31.911	241,716,817	48,086,278	289,803,095	24,438,698	3,915,468	28,354,166	In addition, the N. Y. & B. Bridge carried passengers who didn't continue on the elevated—9.560,806
1900	1,166,382	237.800	37.00	309,530,880	67,008,614	376,539,494	67,814,063	18.922,336	86,736,399	Brighton Beach R. R. included in elevated lines beginning this year
1901	1,180,000	237.800	37.00	331,632,666	62,519,369	394,152,035	22,101.786	—4,489,245	17,612,541	

(Street Railway Journal, October 5, 1901, Page 463)

(Reprinted by E. E. Brownell, September 1, 1919)



THE DAFT ELECTRIC STREET RAILWAY SYSTEM IN OPERATION AT BALTIMORE, MD.



Sidney H. Short's Positive and Negative Trolley System in 1889

(Reprinted by E. E. Brownell, September 1, 1919)

CITIES OF 100,000 POPULATION AND OVER.

Name.	Companies.		Miles single track.	Total track-age.	No. of cars.	No. of Horses.	Locomotives.	Total passengers carried.
	Elevated.	Horse.						
New York	2		60	89	949		291	171,529,789
		19	143	288	2,300	14,441		199,491,735
Brooklyn	3 miles cable included.	14	135	207	2,355	8,410		105,975,249
	3		24	35	247		91	18,632,082
Boston		1	211	231	1,534	7,684		97,039,919
Providence		1	54	54	289	1,414		15,582 732
Chicago	44 lines in one system.	7	325	325	2,400	8,279		99,348,000
Philadelphia		12	302	328	1,512	,322	8 dummies.	143,433,969
St. Louis	3 cable.	14	169	169	1,058	4,231		50,772,000
Baltimore		12	158	158	460	3,167		34,837,000
Cincinnati	2 cable.	30 lines 7	164	164	530	2,644	4 dummies.	31,728,000
New Orleans		7	140	140	499	2,019	18 dum's. 7 loco.	24,228,000
San Francisco	2 steam. 8 cable.	10	163	164	707	1,724	3 loco. 39 dum's.	130,860,000
Buffalo		2	39	56	198	1,276		13,108,203
Washington		5	63	63	336	1,684		21,892,000
Newark		3	53	52	219	1,264		15,168,000
Louisville		2	112	112	378	Mules 2,270		24,970,000
Cleveland		7	123	123	523	Horses 2,521		30,252,000
Pittsburgh	6 cable, 1 electric.	13	113	113	347	1,924	3 dummies.	39,088,000
Jersey City		2	35	35	132	825		10,725,000
Detroit	3 electric.	4	65	65	263	1,682		32,184,000
Milwaukee		3	68	68	208	1,188	2 loco.	16,744,000
Albany		3	19	30	103	424		4,278,927
Indianapolis	Consolidated.	1	40	40	99	648		9,720,000
Kansas City	6 cable.	7	124	124	469	613	38 dum's and mot'rs	33,969,000
St. Paul	1 cable.	1	74	74	154	816		23,608,000
Omaha	2 cable, 3 electric.	1	61	61	167	580	24 motors.	20,540,000
Minneapolis	Consolidated.	1	66	66	160	1,104		14,352,000
Totals		189	3,103	3,414	18,645	77,884		1,434,057,595

Five elevated roads. 27 cable, 147 horse, 7 electric, 3 steam and horse combined—189, total; 18,645 cars, 394 locomotives, 134 dummies and motors; 77,884 horses, 2,270 mules—80,154. About 24,000 horses are annually disabled.

(The Electrical World, August 17, 1889) (Reprinted September 1, 1919, by E. E. Brownell)

All horse car lines in Milwaukee on August 17, 1889

Edward Weston

ABOUT 1888

THE ELECTRIC RAILWAY

(Electrical Review, November 23, 1889, Page 6)

We are in receipt of information showing that there are now in operation in the United States and Canada 102 electric railways, the total mileage of which is 552 miles, and the total number of motor cars 839. This shows an average of about 5½ miles and eight cars for each road. But the list referred to gives in detail the cities and towns in which all the roads are run, and the number of single track miles, and the cars employed in each. The following analysis of the list will furnish an interesting exhibit of the present situation of this important matter:

Roads in Cities Over 100,000 Population

	Miles	Cars		Miles	Cars
New York	18.5	10	St. Louis	5.5	12
Boston	14	31	Washington	3	10
Albany	15.5	16	Baltimore	2	4
Cincinnati	12	31	New Orleans	..	1
Cleveland	30	10			
Louisville	10	10		118	191
Detroit	7.5	6			

Cities Over 25,000 and Under 100,000

	Miles	Cars		Miles	Cars
Rochester	7	9	Richmond	13	41
Syracuse	4	8	Wheeling	10	5
Troy	5	12	Erie	12	5
Columbus	2	2	Reading	2	4
Dayton	9	12	Scranton	20.5	37
Nashville	3	6	Davenport	3.5	6
Harrisburg	7.5	10	Des Moines	10	8
Lynn	6.8	9	Salem, Mass.	2	6
Plymouth	4.5	3	Atlanta	4.5	4
Wilkesbarre	3	8	Allegheny	3.7	6
Wilmington	3	8			
Omaha	26	72		162	281

ABANDONING CABLES FOR ELECTRICITY AT GRAND RAPIDS, MICHIGAN

(The Electrical Engineer, December 31, 1890, Page 729)

Director Hagar, of the Grand Rapids Consolidated Street Railway Co., which has a million dollar cable system, says that they will put in probably 45 miles of electric road next year. They have 14 miles of cable road which will be abandoned, the cable cars being replaced by electric cars, and overhead wires being strung above the present cable tracks. It is said to be likely that the Short system will be used.

WEST END STREET RAILWAY COMPANY, BOSTON, MASSACHUSETTS, 1889 TO 1894

(Beginning of electrification and continuing five years to completion)

Year ending Sept. 30,	1889.	1890.	1891.	1892.	1893.	1894.
STATISTICS OF TRAFFIC.						
Round trips run	2,205,359	2,344,570	2,328,274	2,259,858	2,303,462	2,319,377
Revenue miles run, horse cars	16,048,465	14,353,617	12,874,426	8,988,377	4,448,962	2,445,525
" " " electric cars	525,366	3,311,743	4,588,146	8,510,283	14,220,847	16,794,961
" " " total	16,573,831	17,665,360	17,462,572	17,490,660	18,669,809	19,240,486
Revenue passengers carried	104,243,150	114,853,081	119,264,401	126,210,781	133,863,618	137,028,449
PASSENGER RECEIPTS.						
Passenger receipts, horse cars	....	....	....	$2,907,097	$1,301,341	$662,125
" " electric cars	....	....	....	$3,330,549	$5,315,266	$6,072,186
" " total	$5,171,975	$5,678,390	$5,889,180	$6,237,646	$6,616,607	$6,734,311
Average receipts per passenger	$.04961	$.04944	$.04938	$.04942	$.04943	$.04914
Passenger receipts, per car mile, horse cars	....	....	....	.323	.292	.271
" " " " electric cars	....	....	....	.391	.374	.362
" " " " average	.312	.321	.337	.356	.354	.350
OPERATING EXPENSES PER CAR MILE.						
General expenses	[g]$.0243	[g]$.0272	$.0188	$.0208	$.0215	$.0218
Maintenance of track	.0147	.0142	.0116	[a].0136	.0151	[b].0137
" " buildings	.0040	.0027	.0039	.0031	.0036	.0022
" " cars & vehicles	[f].0161	.0113	.0115	.0126	.0160	.0212
" " horse equipment[c]	.0187	.0178	.0210	.0247	.0115	.0532
" " electric equipment[d]	.....	.....	.0300	.0302	.0241	.0213
Road and snow expense	.....	.0046	.0077	.0076	.0106	.0085
Transportation expenses	.1694	.1653	.1694	.1590	.1441	.1305
Injuries and damages	.....	.....	.0085	.0118	.0118	.0125
Total (average)[e]	.2473	.2396	.2546	.2559	.2437	.2499

[a] Plus $.0103 charged to "track improvement account." [b] Plus $.0042 charged to "track improvement account." [c] Total expense divided by horse mileage only. [d] Total expense divided by electric mileage only. [e] This is not the sum of the separate items, see notes c, d. [f] Including maintenance of tools and machinery. [g] Including injuries and damages.

(The Street Railway Journal, April, 1895, Page 224) (Reprinted by E. E. Brownell September 1, 1919)

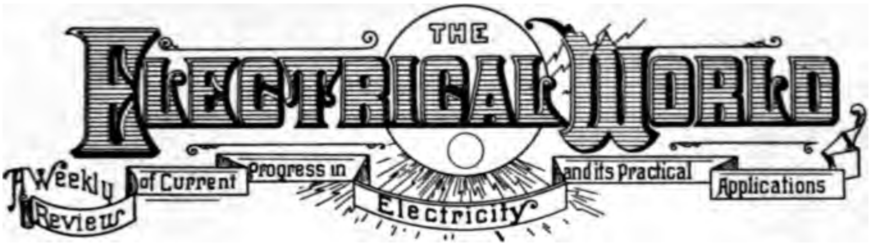
CHARLES J. VAN DEPOELE

Born in Litchervelde, Belgium, 1846

Died in United States, March 18, 1892

ELECTRIC STREET RAILWAYS IN AMERICA

In Operation


THE
ELECTRICAL WORLD
A Weekly Review of Current Progress in Electricity and its Practical Applications

(October, 1889, Page 457)

Location	Operating Company	Length in Miles	No. of M. Cars	System
Akron, Ohio	Akron Electric Ry. Co.	6.5	12	Sprague
Albany, N. Y.	Wt'rvt T'pike & R.R. Co.	15.5	16	Thomson-Houston
Atlanta, Ga.	Atl. & Edg'wd St. Ry Co.	4.5	4	Thomson-Houston
Allegheny, Pa.	Observ. Hill Pas. Ry. Co.	3.7	6	Bentley-Knight
Alliance, Ohio	Alliance St. Ry. Co.	2	3	Thomson-Houston
Ansona, Conn.	Derby Horse Ry. Co.	4	1	Thomson-Houston
Appleton, Wis.	Ap. Electric St. Ry. Co.	5.5	6	Van Depoele
Asbury Park, N. J.	Seashore El. Ry. Co.	4	20	Daft
Asheville, N. C.	Asheville St. Railway	3.5	5	Sprague
Atlantic City, N. J.	Pennsylvania R. R. Co.	6.5	16	Sprague
Baltimore, Md.	Balt. Un. Pass. Ry. Co.	2	4	Daft
Bangor, Me.	Bangor St. Ry. Co.	5	4	Thomson-Houston
Bay Ridge, Md.	Bay Ridge Elec. R. F.	2	2	Sprague
Binghamton, N. Y.	Washington St., Asylum & Park R. R.	5	4	Sprague
Boston, Mass.	West End St. Ry. Co., Brookline Branch	11	23	Sprague
Boston, Mass.	West End St. Ry. Co., Harvard Sq. Branch	14	31	Thomson-Houston
Brockton, Mass.	East Side Street Ry. Co.	4	4	Thomson-Houston
Buffalo, N. Y.	Buffalo St. Ry. Co.	2.5	4	Sprague
Carbondale, Penn.	Carbondale and Jermyn Street Railway	1.5	3	Sprague
Cincinnati, Ohio	Mt. Adams & Eden Park Inclined Ry. Co.	1	3	Daft
Cincinnati, Ohio	Cin. & Inclined Pl. Ry.	6	20	Sprague
Cincinnati, Ohio	Colerain Ave. Ry. Co.	5	8	Thomson-Houston
Chattanooga, Tenn.	Chat. Elec. St. Ry. Co.	5	6	Sprague
Cleveland, Ohio	East Cleveland Rd. Co.	8	16	Sprague
Cleveland, Ohio	Brooklyn St. Ry. Co.	18	10	Thomson-Houston
Cleveland, Ohio	Collamer Line, E. Cleveland, Ohio	3	8	Sprague
Columbus, Ohio	Columbus Consolidated St. Railway Co.	2	2	Short
Crescent Beach, Mass.	Lynn & Bos. St. Ry. Co.	1	1	Thomson-Houston
Davenport, Iowa	Davenp't Cen. St. Ry. Co.	3.5	9	Sprague
Danville, Va.	Danville St. C. Co.	2	4	Thomson-Houston
Dayton, Ohio	White Line St. R. R. Co.	9	12	Van Depoele
Decatur, Ill.	Citizen's Elec. St. Ry.	5	4	Thomson-Houston

ELECTRIC STREET RAILWAYS IN AMERICA

(Continued)

Location	Operating Company	Length in Miles	No. of M. Cars	Syste
Decatur, Ill.	Decatur Elec. St. Ry.	3	1	Nat. Elec.
Des Moines, Iowa	Des M. B'd G'g Ry. Co.	10	8	Thomson-
Detroit, Mich.	Detroit Electric Ry. Co.	4	2	Van Depo
Detroit, Mich.	Highland Park Ry. Co.	3.5	4	Fisher
Easton, Pa.	Lafayette Traction Co.	1	2	Daft
Eau Claire, Wis.	Eau Claire St. Ry.	5	6	Sprague
Erie, Pa.	Erie City Pass. R. R. Co.	12	20	Sprague
Fort Gratiot, Mich.	Gratiot Elec. Railway	2	2	Van Depo
Harrisburg, Pa.	E. Harrisburg P. Ry. Co.	7.5	10	Sprague
Hartford, Conn.	Hartford & Weatersfield Horse Railroad Co.	3	4	Sprague
Ithaca, N. Y.	Ithaca St. Railway Co.	1	2	Daft
Jamaica, N. Y.	Jamaica & Brooklyn R.R.	9	10	Van Depo
Lafayette, Ind.	Lafayette Street Ry. Co.	3	9	Sprague
Laredo, Texas	Laredo City R. R.	4	4	Sprague
Lima, Ohio	The Lima Street Railway Motor & Power Co.	6	7	Van Depo
Los Angeles, Cal.	Los Angeles El. Ry. Co.	5	4	Daft
Louisville, Ky.	Central Pass. R. R. Co.	10	10	Thomson-
Lynn, Mass.	Lynn & Boston Ry. Co. (Crescent Beach)	1	1	Thomson-
Lynn, Mass.	Lynn & Boston R.R. Co. (Nahant Line)	.8	1	Thomson-
Lynn, Mass.	Lynn & Boston R.R. Co. (Highland Line)	2	3	Thomson-
Lynn, Mass.	L. & B. Rd. Myrtle St. L.	3	4	Thomson-
Mansfield, Ohio	Mansfield El. St. Ry. Co.	4.5	5	Daft
Marlboro, Mass.	Marlboro St. Ry. Co.	3	2	Sprague
Meriden, Conn.	New Horse Railroad	5	12	Daft
Meriden, Conn.	Meriden Horse R. R. Co.	5	12	Daft
Nashville, Tenn.	McGavock & Mt. Vernon St. Ry.	3	6	Thomson-
Newark, N. J.	Essex Co. Pass. Ry. Co.	2.5	4	Daft
New York, N. Y.	N. Y. & Harlem (Fourth Avenue) R. R. Co.	18.5	10	Julien
New Orleans, La.	....		1	Daft m'tr son st'g
Newport, R. I.	Newport St. Ry. Co.	4.5	6	Thomson-
Omaha, Neb.	Omaha & Council Bluffs Railway & Bridge Co.	2	24	Thomson-
Omaha, Neb.	Omaha Motor Ry. Co.	10	26	Thomson-
Omaha, Neb.	Omaha Horse R. R.	10	20	Sprague
Omaha, Neb.	Omaha & C. Bluffs R. R.	4	2	Sprague
Ottawa, Ill.	Ottawa Elec. St. Ry. Co.	5	8	Thomson-
Plymouth, Mass.	Ply. & Kingst'n Ry. Co.	4.5	3	Thomson-
Port Huron, Mich.	Port Huron Electric Ry.	4	6	Van Depo
Reading, Pa.	East Reading R. R. Co.	2	3	Sprague
Revere, Mass.	Revere Beach Ry. Co.	1	1	Thomson-
Revere, Mass. (Ex.)	Revere St. Ry. Co.	2.5	5	Thomson-
Richmond, Va.	The Richmond Un. Pass. Railway Co.	13	46	Sprague
Richmond, Ind.	Richmond St. Ry. Co.	4	6	Thomson-

ELECTRIC STREET RAILWAYS IN AMERICA

(Continued)

Location	Operating Company	Length in Miles	No. of M. Cars	System
Rochester, N. Y.	Rochester Elec. Ry. Co.	7	9	Thomson-Houston
Salt Lake, Utah	Salt Lake City R. R. Co.	6.5	10	Sprague
Salem, Mass.	Naumkeag St. Ry. Co.	2	6	Sprague
San Diego, Cal.	San Diego St. Ry. Co.	9	4	Henry
San Jose	San Jose & Santa Clara R. R. Co.	10	6	Fisher
Seattle, Wash. Ter.	Seattle Electric Railway and Power Co.	5	9	Thomson-Houston
St. Catherine's, Ont.	St. Cath. Merritton and Thorold St. Ry. Co.	7	10	Van Depoele
St. Joseph, Mo.	St. Jos. Un. Pas. Ry. Co.	6	12	Sprague
St. Joseph, Mo.	Wyatt Park Ry. Co.	10	17	Sprague
St. Joseph, Mo.	Wyatt Park Railway Co. (Northern Div.)	4.5	9	Sprague
St. Joseph, Mo.	People's R. R. Co.	10	20	Sprague
St. Louis, Mo.	Lindell Ave. R. R.	5½	10	Sprague
Scranton, Pa.	The People's Street Ry.	12	20	Sprague
Scranton, Pa.	Scranton Sub. Ry. Co.	5	10	Thomson-Houston
Scranton, Pa.	Nay Aug Cross-Town Ry.	1.5	4	Thomson-Houston
Scranton, Pa.	Scranton Passenger Ry.	2	4	Thomson-Houston
Southington, Conn.	Southington & Plantsv'le Ry. Co.	2	2	Thomson-Houston
Syracuse, N. Y.	Third Ward Ry. Co.	4	8	Thomson-Houston
Steubenville, Ohio	Steubenville El. Ry. Co.	2.5	6	Sprague
Stillwater, Minn.	Stillwater Elec. St. Ry.	5	6	Sprague
Topeka, Kan.	Topeka Rapid Trans. Co.	17	30	Thomson-Houston
Troy, N. Y.	Troy & Lansingburg St. R. R.	5	6	Sprague
Washington, D. C.	Eckington & Soldiers' H. Elec. Railway Co.	3	10	Thomson-Houston
Wheeling, Va.	Wheeling Railway Co.	10	5	Thomson-Houston
Wichita, Kan.	Riverside & Sub. Ry. Co.	9	6	Thomson-Houston
Wichita, Kan.	Wichita & Sub. Ry. Co.	7.5	7	Sprague
Wilkesbarre, Pa.	Wilkesbarre & Suburban St. Railway Co.	3	7	Sprague
Wilmington, Del.	Wilmington City Ry. Co.	3	4	Sprague
Windsor, Ont.	Windsor El. St. Ry. Co.	2	2	Van Depoele

Total—Roads 103
" Miles 541
" Motor Cars............. 851

(The three electrification ordinances were passed in City of Milwaukee, Wis., on October 14, 1889, and the operation of the first electric street car was on April 4, 1890.)

ELECTRIC STREET RAILWAYS IN AMERICA

Constructing or Under Contract

THE ELECTRICAL WORLD

A Weekly Review of Current Progress in Electricity and its Practical Application

(October, 1889, Page 457)

Location	Operating Company	Length in Miles	No. of M. Cars	System
Adrian, Mich.	Adrian Elec. Railway	3		Nat. Elec.
Adrian, Mich.	Adrian City Belt Line El. Ry. Co.	3	4	Rae
Akron, Ohio	Akron Elec. Ry. Co.	6	22	Sprague
Atlanta, Ga.	Fulton Co. St. Ry. Co.	9	8	Thomson-
Attleboro, Mass.	No. Attleboro & Wrentham St. Ry. Co.	8	5	Thomson-
Americus, aG.	Americus St. Ry. Co.	5.5	4	Thomson-
Auburn, N. Y.	Auburn Elec. Ry. Co.	3	3	Thomson-
Boston, Mass.	W. End St. Ry. Co., City Line, Bolyston & Beacon Streets	230	300	Thomson-
Cincinnati, Ohio	Cincinnati St. Ry. Co.	2.7	8	Thomson-
Chattanooga, Tenn.	Chattan'ga El. St. Ry. Co.		2	Thomson-
Cleveland, Ohio	B'way & Newb'gh St. Ry.	10	16	Sprague
Cleveland, Ohio	E. Cleveland St. R. R., Prospect St. Line	5	32	Sprague
Dallas, Texas	Dallas Rapid Tran. R. R.	3	2	Sprague
Dallas, Texas	West Dallas St. R. R.	3	2	Sprague
Detroit, Mich.	E. Detroit & Grosse Pt. Railway	8		Nat. Elec.
Detroit, Mich.	Detroit City Ry., Mack Street Line	2		Nat. Elec.
Detroit, Mich.	Detroit, Rouge River & Dearborn R. R.	1	1	Sprague
Denver, Colo.	University Park Ry. & Electric Co.	4	3	Thomson-
Denver, Colo.	So. Denver Cable Co.	2	2	Sprague
Dubuque, Iowa	Key City Electric Ry.	2	4	Sprague
Elkhardt, Ind.	Citizens St. Railway	7		Nat. Elec.
Fort Worth, Texas	Fort Worth City Ry. Co.	10		Nat. Elec.
Fort Worth, Texas	Ft. W. L'd & St. Ry. Co.	15		Nat. Elec.
Huntington, W. Va.		3.5	2	Short
Joliet, Ill.	Joliet St. Ry.	3	4	Thomson-
Kansas City, Mo.	No. East St. Ry. Co.	7	10	Thomson-
Kansas City, Mo.	Vine St. Ry.	3	6	Thomson-
Kansas City, Mo.	Metropolitan St. Ry. Co.	4.5	4	Thomson-
Long Island City, N. Y.	Long Island City & Newton Elec. R. R.	3	2	Sprague
Lynn, Mass.	Belt Line Ry. Co.	4.5	4	Thomson-

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CTRIC STREET RAILWAYS IN AMERICA (Continued)

Location	Operating Company	Length in Miles	No. of M. Cars	System
, Ill.	Moline St. R. R.	3	2	Sprague
ester, Va.	Richm'd & Man. Ry. Co.	3.5	10	Sprague
apolis, Minn.	Minneapolis St. Ry. Co.	6.5	6	Sprague
apolis, Minn.	Minneapolis St. Ry. Co.	8	10	Thomson-Houston
gon, Mich.		4.5	5	Short
ille, Tenn.	Nashville St. R. R.	5	8	Sprague
ryport, Mass.	Newburyport & Amesbury Horse Ry. Co.	6	2	Thomson-Houston
n, Mass.	Newton St. Ry. Co.	8	10	Thomson-Houston
ork, N. Y.	No. & East River Ry. Co.	3	20	Bentley-Knight
Adams, Mass.	Hoosac Valley St. Ry.	5	6	Thomson-Houston
o, Cal.	Ontario & San Antonio Heights Ry. Co.	8	4	Daft
wa, Ia.	Ottumwa St. Ry. Co.	5	4	Thomson-Houston
c, N. J.	Passaic St. Ry.	3	3	Thomson-Houston
, Ill.	Central Ry. Co.	10	15	Thomson-Houston
Ohio	Piqua Electric R. R.	3.5	4	Sprague
urgh, Pa.	Federal St. & Pleasant Valley R. R.	8½	25	Sprague
urgh, Pa.	Pittsburgh Sub'an Rapid Transit Co.		3	Daft
urgh, Pa.	Squirrel Hill R. R.	3½	5	Sprague
urgh, Pa.	Second Ave. Pas. Ry. Co.	10	10	Thomson-Houston
mouth, Neb.	Plattsmouth El. R. R.	2	2	Sprague
hester, N. Y.	P. C. & Rye B. St. Ry. Co.	3	5	Daft
nd, Oregon	Metropolitan R. R.	3	4	Sprague
nd, Oregon	Willamette Bridge Co.	1.5	5	Sprague
y, Mass.	Quincy St. Ry.	5	4	Thomson-Houston
ank, N. J.	Red Bank & Seabr't Ry.	5	3	Thomson-Houston
ond, Va.	Richmond City Ry. Co.	7.5	50	Sprague
uis, Mo.	St. Louis Bridge Co.	2	4	Thomson-Houston
uis, Mo.		3	13	Short
. Mass.	Naumkeag St. Ry.	3	6	Thomson-Houston
ga Spgs, N. Y.	Saratoga Elec. Ry. Co.	2	4	Thomson-Houston
Ste. Marie, Mich.	Sault Ste. M. St. Ry. Co.	2		Fisher
sky, Ohio	Sandusky Electric Ry.	6.75	6	Sprague
ton, Pa.	Hillside Coal Co.	1	1	Thomson-Houston
St. Paul, Minn.	S. St. P. Rapir Tran. Co.	8	10	Daft
ne Falls, W. T.	Ross Park St. Ry. Co.	7.50	6	Thomson-Houston
field, Mo.				Fisher
ng, Ill.	Union Electric R. R.	6	7	Sprague
ry, Pa.	Sunbury & N. Ry. Co.	3½	3	Daft
na, Wash. Ter.	Pacific Ave. St. R. R.	6	6	Sprague
na, Wash. Ter.	Tacoma Ave. St. Ry. Co.	2	4	Sprague
o, Ohio	Toledo Slec. Ry. Co.	2	2	Thomson-Houston
uver. Island	Victoria El. St. Ry. Co.	4	4	Thomson-Houston
ington, D. C.	Georget'n, Tenalleytown St. Ry. Co.	6	3	Thomson-Houston
sbarre, Pa.	Wilkesbarre & West Side R. R.	4	3	Sprague
ester, Mass.	Worcester & Shrewsb'ry	2.7		Daft
Bay City, Mich.	W. Bay City El. Ry. Co.	5	8	Sprague

Total—Roads................. 76

The electrification period had not started as yet in the City of Mil-
ee, Wisconsin.)

ADDRESS OF FRANK J. SPRAGUE, 1890

THE STREET RAILWAY JOURNAL

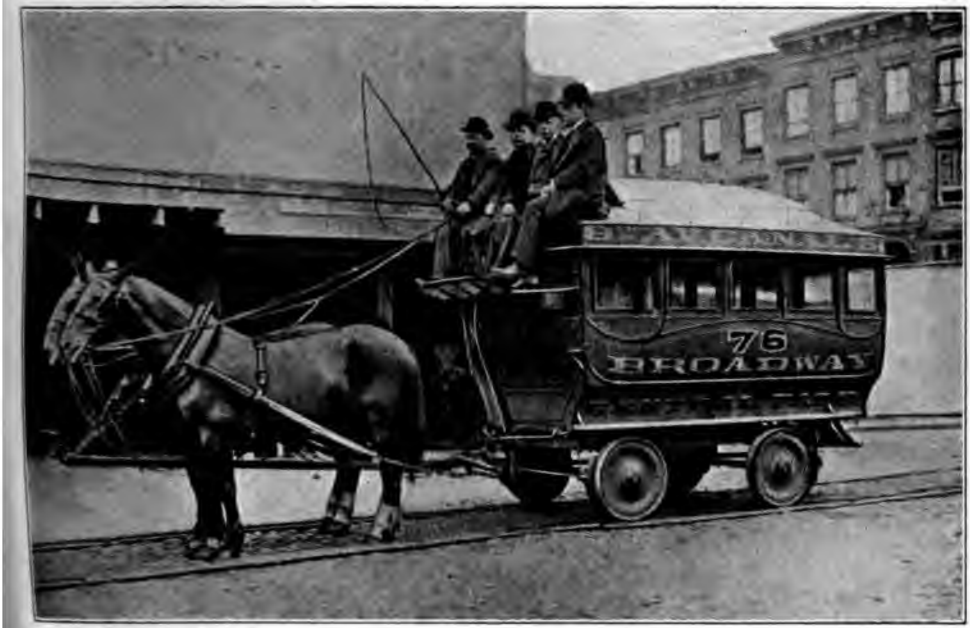
(The Street Railway Journal, Vol. II, Pages 150-1-2-3, 1890)

Mr. President and Delegates: Scarcely fifteen years—a period of time yet within the memory of the youngest of us—have passed since the beginning of a new era, the transmission of energy for light, power and the reproduction of speech. Of the progress of the first I need not speak, for the delegates of this convention are well cognizant of its history and the advance it has made within that time. The spread of the telephone to nearly every town and hamlet in the fourteen years since it was exhibited as a scientific toy at Philadelphia, and the financial success of the parent company, are facts continually before your minds or ringing in your ears. But that great industry, the transmssion of electricity for power, with its possibilities of all kinds, is of very recent development. Six years ago there were scarcely a hundred electric motors in operation in the United States for any purpose; to-day there are no less than 15,000 motors in use, applied to not less than 200 different industries, and an industrial revolution is taking place equalling, if not surpassing, in importance that attending the introduction of the steam engine, and marvelous in the rapidity of its growth.

It is not my purpose to dwell at length upon the subject of the transmission of power by electricity in its general application, but to touch upon one branch only, that of railway work, reviewing very briefly the development in the United States, pointing out the salient features of successful operation, noting what has been already accomplished, and after some remarks upon the legal questions which have arisen, considering the possibilities of the future.

The modern electric railway may be said to have been born in Europe, its babyhood was in Europe; but in its youth and younger manhood it is purely American. In 1881, Dr. Siemens, of Berlin, established the pioneer railway on the Lichtenfelde line in the suburbs of Berlin, and I believe it is still running. It was followed by other roads, some commercial and others for exhibition, erected by the firm of Siemens, and by work done by other electrical engineers. The Siemens also established a line at Frankfort. The Doctors Hopkinson established one at Portrush, Ireland. Another was established at Blackpool. This last was a conduit system. A double metallic overhead system was established in 1888 at Vevay, Switzerland, and comparatively recently the Siemens have established a conduit system at Buda-Pesth.

The first line which was established in the United States for actual commercial service was a suburban line of two miles in length, built by Mr. Daft just outside of Baltimore, in the latter part of 1885, using a central rail. Other lines were established by Mr. Van Depoele in various parts of the country, using the single and double trolley system with the trolley traveling upon and carried by the wire, and connected to the car by a flexible cable.



A tram car of Sixty years ago in New York City.

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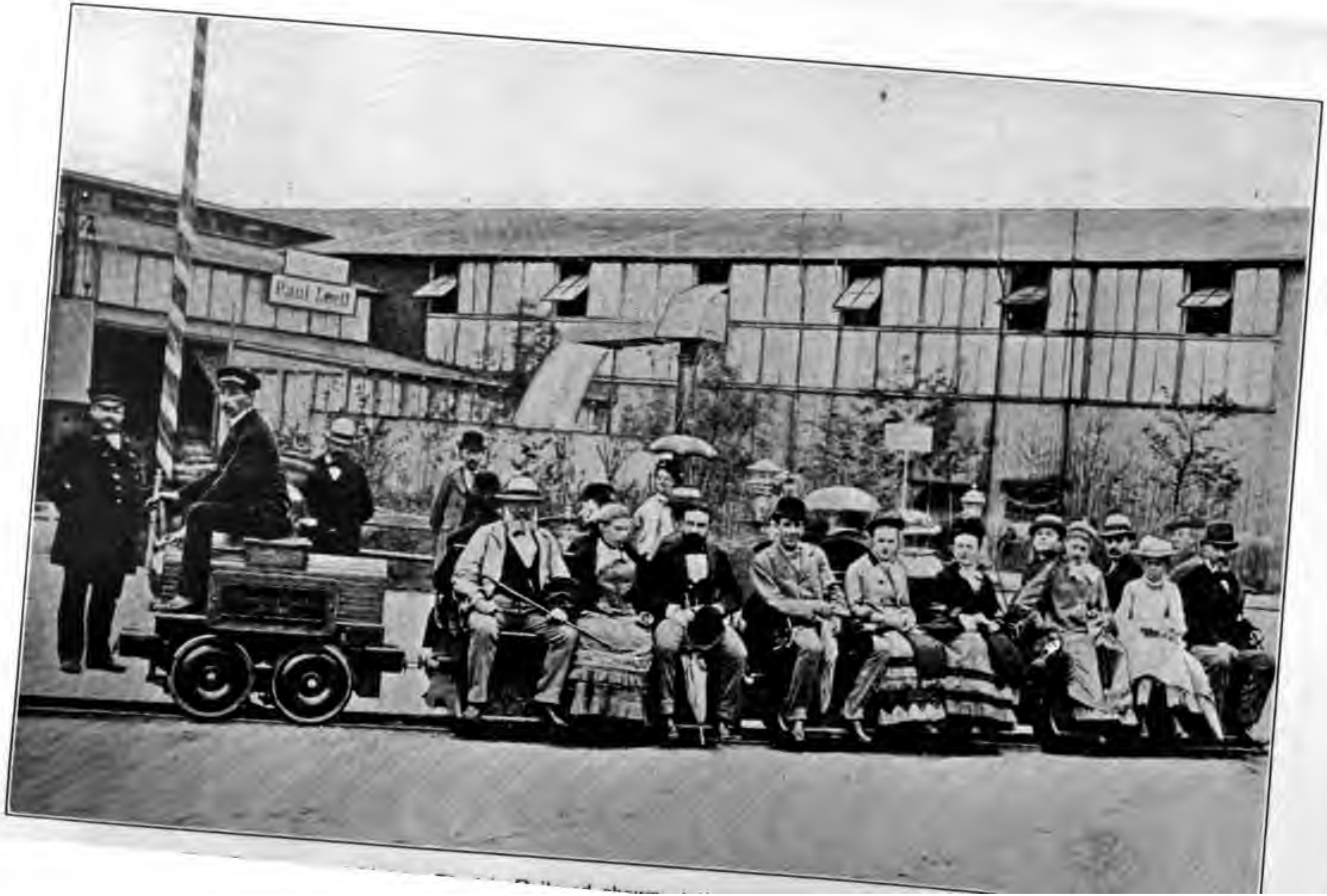

Paul Lenz

In all this pioneer work the system used was that of direct supply, but most of the mechanical features as well as the electrical details have now given way to other and more efficient methods of operation..

Of the more recent work three classes demand attention, one being the system of independent units operated by the storage battery and the other two being direct systems of supply, one underground, the other overhead. I shall not enter into details of these three systems or their modifications, for it would be a repetition of much which has already been written, but I will briefly state the facts, and the conclusion I have formed concerning them.

There is something exceedingly attractive in the proposed application of storage batteries to the propulsion of cars. To be able to conveniently store up a large amount of energy in a box, put it aboard a car, carry it around with us, and take from it greater or less amount of work, offers, when practicable, a solution of the street car problem for which we are all devoutly hopeful. But looking at it commercially, the storage battery is still a long way from being a serious competitor of the direct source of supply. True, great improvements have been made in it, but these improvements have not very much altered its character, or the weight which is necessary, or the care which must be exercised in getting an economical return from the battery. These improvements have made it possible to take a heavier charge from the battery without producing buckling, have made a rougher usage of the battery mechanically possible, and have in some instances greatly reduced its cost of manufacture, so that the element of maintenance is a less serious one than it was a year or two ago, but the capacity of the battery, while it has been somewhat increased, remains such that it is still necessary to have about 3,500 lbs. to propel an ordinary street car. This means an excessive weight. It takes of space and is a serious extra load to be carried around. It requires frequent shifting, and its capacity as well as discharge rate is so limited that it is simply impossible to work such a battery upon grades which are at all severe. I believe it is possible with care to operate a storage battery on grades not exceeding, say, four per cent., and with limited speed and daily mileage at an expense about equal to that of horses, or a little less, but still at about double the expense which is necessary upon a suitably erected and properly operated overhead system.

Nowhere in the United States, that I am aware of, is there serious storage battery work being done at the present moment. The nearest attempt was where recent experiments were made on the Madison Avenue line, New York City, where about a dozen cars were being run up until eight o'clock in the evening, but owing to legal complications only two cars are now running there —with what daily mileage I do not know. But nowhere is the work done at all equivalent to what is constantly practiced on the overhead line. On that service motor cars start out at five or six o'clock in the morning and run until midnight. Many cars make 150 or 160 miles a day, and some cars have even made 180 and 190 miles a day. Half of this for storage battery work is good duty, but it is not up to the demands which street railway managers make, and until the radical improvements which are promised are made in it, the field of application will be limited.

The conduit system of direct supply has been attempted in several places, notably at Denver, Cleveland, Allegheny City and Boston, but at all the places mentioned these experiments have proved disastrous and have been abandoned, save the short section at Allegheny City. In England, the Blackpool line, under special conditions, has been, I believe, fairly successful, and at Buda-Pesth the Messrs. Siemens have a conduit system in successful operation. There, however, the drainage is very perfect, and in addition a man is detailed for given sections of the track, and is continually employed in patrolling his section and clearing it out. Assuming good sewerage, the conduit can unquestionably be made to work. It becomes then a question of cost, but for general application, especially in view of the fact that most of our cities do not have a sewerage system which can take care of the street drainage, the expense is prohibitory save on large systems under exceptional conditions. I look forward to the time when many existing well constructed and well drained cable conduits will become electrical conduits, and electricity will then score another victory.

The system, however, which has made such a marked advance is the single trolley overhead system with universally flexible underneath contact, and this has been the growth of the past two and a half years. I think I can fairly claim for the Sprague Co. the pioneer place in this development, but the commercial development on the lines it laid down has been with great energy pushed forward principally by both it and the Thomson-Houston Co. The first work done by the Sprague Co., other than experimental work on the elevated railroads, was made but a short distance from this city. A single car was started in 1887 on the Union Passenger Railway Co.'s line in St. Joseph, with a small seven and a half H. P. motor, single geared, and adapted to run at a very high speed on a suburban extension. It is a matter of interest that that road has seen nearly every change made in the system. Its lines have been extended twice, and it has both the old style motors and the more modern equipments. But all the work done on that line was, it may be said, purely experimental, and it was not until the 2d of February that the Richmond road was officially opened to the public.

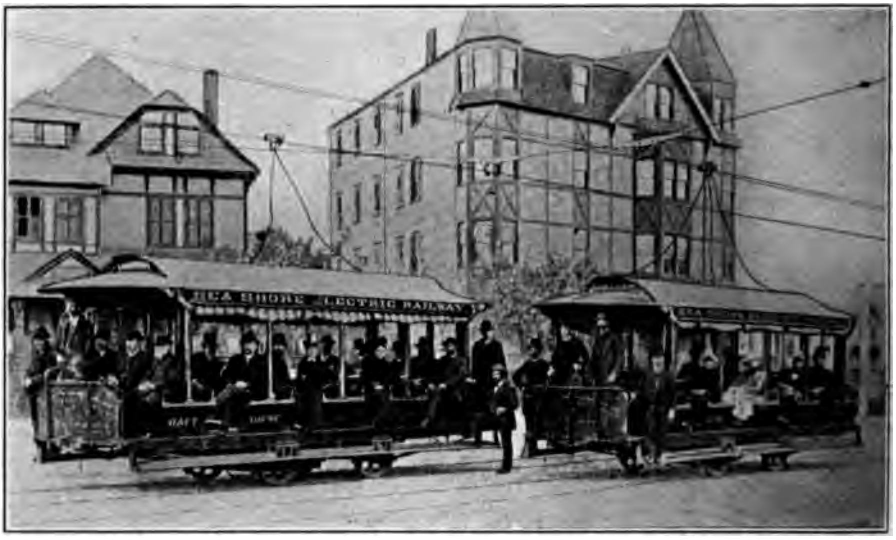
* * * * * * * * * * * *

The Richmond experiment has passed into history. It has had its vicissitudes, it has had its victories as well. But it remains, with all its crudities and with all the accidents which have marked its career, as the one great step in advance, whose features, in the main, have been followed in almost all the recent electric railways. Machines have been made larger, they have been made mechanically and electrically more perfect. Changes of detail have been frequent, but most of the characteristic features there outlined mark to-day nearly every electrical railway which is either in operation, in process of construction, or under contract.

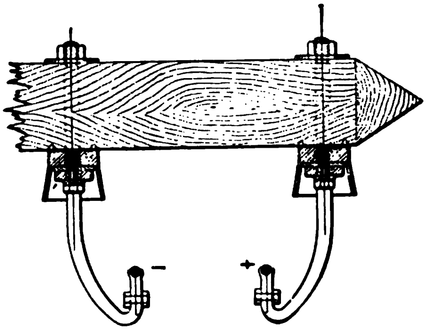
Taking our work alone and that of 1887 as a basis, in 1888 it was trebled. The work of 1888 was quintupled in 1889. As to what it will be in 1890 I will not hazard a guess. Its strongest opponents two years ago are now its best friends, and the enterprise, for which it was then difficult to get a dollar investment, to-day demands the best thought and the most active energies of two great corporations and a number of smaller ones. The contracts for electrical equipments involve larger amounts than almost any other electrical enterprise. The business done in this year will probably be not less than $6,000,000. Every street railway in the United States is watching with eager eyes the developments of the rival electrical interests. The friends of the cable system are on the defensive. The advocates of the electric system are reliant and aggressive. Its flexibility, the ease with which it is extended, its adaptability to various conditions of service, its freedom from the long continued breakdown, the marvelous advances which have been made in perfecting its apparatus, all insure its supremacy.

As illustrating the progress of electric railways, I may state that there are about 130 towns or cities in the United States with one or more electric railways in operation, construction or under contract, and that these roads comprise about 1,500 miles of track, equipped with 1,700 motor cars, requiring 3,000 motors, of an aggregate capacity of 45,000 H. P., and steam and electrical generators of 25,000 H. P. The roads in operation are making about 100,000 miles per day, and within three months the mileage will be doubled.

As regards danger, the electric car is the safest possible vehicle, because of the remarkable facility of control, and as to the objections to the overhead line on the score of danger which have been raised sometimes by the municipal authorities, and which have been cited by the telephone interests, they are, we may safely say, imaginary rather than real. Some two years and a half ago I settled upon 400 volts as a fairly satisfactory standard of potential for which the motor for street railway service should be built, allowing about ten per cent. drop in the distribution on the line, making the potential in the station about 440 to 450 volts. In some cases, where dealing with heavy work on extended lines and small conductors we have raised the potential at the motors to about 450 volts, making no change whatever in the machine, and have run the central station at 480 to 500 volts. There are in the United States about eighty electric



The Electric Railway at Asbury Park, N.J., U.S.A., in 1887. Span wire construction with two trolley wires, positive and negative, and a four-wheeled trolley running on top of these wires. Connection with the cars was made by flexible cable.



Insulated hangers for the two overhead conductors, positive and negative.

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railways in operation. Almost every employe of the contracting companies and a great many employes of the railway companies themselves, including not only the linemen, and those whose business it is to work upon the electrical equipment, but also the conductors and drivers, have received shocks from these lines of greater or less duration, and under almost every possible condition. Yet in no instance which ever came under my observation, or of which we have any reliable record, has serious injury resulted from the shock of the current itself. When we consider that these shocks have occurred to persons of all ages and of all physical conditions, and for varying periods, the experience seems to be quite ample to warrant the assertion, that as ordinarily constructed, a constant potential circuit of 500 volts is not dangerous to human life, and we can dismiss that question.

Reviewing the work of the past two years, that which was promised for electricity has been in the main entirely fulfilled. It has proved itself capable of doing the most extraordinary work under the most unfavorable conditions. Grades of twelve and a half per cent., and more recently of fourteen per cent., have been ascended with loaded cars. Grades three miles long, varying from four to eight per cent., have been ascended by motor car pulling a tow car. It has done work where it would have been impossible to have done it by horses. It has enabled the running speed of cars to be increased even in crowded cities fifty per cent.; and on suburban routes speeds of twenty miles or more have been made. Experimental runs of thirty miles an hour on the ordinary street car with the narrow flange wheel have been attained; and on special experiments a speed of nearly 150 miles has been made for a short distance. The electric car has shown that it can run faster on both up and down grades, that it can be gotten under way and stopped more quickly than a horse car; that with any given number of cars the mileage has been increased and the same time intervals made with a less number of cars. Many cars have made from 180 to 190 miles in one day. Horse space having been saved, the equipments occupy a third less space, and this fact, coupled with the ability to back when necessary and again quickly gain headway has enabled an electric railway car in crowded and narrow streets to work its passage where a horse car would be at a dead standstill. Not only has the possibility of running down grade faster been established, but that possibility with a high degree of safety, because in the event of losing control of a car by the brakes, the instant reversal of the motor will bring the car to a standstill. This has frequently been the experience, and in one case which was recently reported to us, the inspector stated that a car was going nearly thirty-five miles an hour on the down grade before the driver attempted to reverse his machine; but when he did reverse it, he brought his car to a standstill with the loss of only one gear. Making due allowance for the possible excitement of the inspector, I think the car was moving at least twenty-five miles an hour when the reversal took place.

The riding of an electric car is unquestionably easier than on the majority of cable or horse cars, starting and stopping more easily, and being in a very large measure free from oscillation. It is scarcely necessary to say that the cars are cleaner, that they are brilliantly lighted, and that it would be possible even to heat them by electricity. The sanitary conditions are entirely altered, and the health and comfort of the people conserved by doing away with stables, with all their unsavory characteristics and resultant injury to the value of adjacent real estate. Branch lines of every possible combination of grade, curve and ill-conditioned street, which has so often proved prohibitory to any other system of propulsion, have been operated by the electric system. Distances up to six miles or more away from a single station have been operated without difficulty, and large numbers of cars from one station. It can very properly be said that there have been many breakdowns; that machines have depreciated; that there have been exasperating troubles. True, these things have happened, and in case of defective workmanship and of careless inspection or management, they will happen again no matter what system of propulsion is adopted. The accidents which can happen to a motor come within a very limited category, and the liability of a motor to these accidents is being very rapidly reduced to a minimum, till it is becoming to-day the most perfect piece of machinery, capable of the longest continued use and a large amount of abuse. The very accidents which have happened, as simple as the causes are—and I may say here that nine-tenths of electrical troubles are due to mechanical defects—and the very makeshifts which have been temporarily resorted to, to overcome the troubles and keep the lines in operation, are the best evidence of the flexibility of the system and the perfection to which it will arrive. No other machine in existence has, in so short a period of development, been brought to such a degree of perfection, is capable of such varied application, and can be so quickly and easily understood.

The cost of operation has proved entirely satisfactory, and my early claim has been substantiated. In a paper read before the American Institute of Electrical Engineers in August, 1888, and also in some earlier communications, I made an estimate as to the expense of operating a thirty car road, dividing these operating expenses under two heads: (1), Those belonging to the central station; and (2), what may be called the road operating expenses, the sum of the two constituting the total cost of motive power. In making this estimate I used extra care, and while preserving its accuracy, made every reasonable allowance that I thought necessary. The conclusion at which I arrived, in the estimate under the conditions there given, was, that the total cost of motive per car mile should not exceed four and three-tenths cents; and this included everything except executive and salary expenses, taxes and insurance, and other matter not connected with motive power. I also stated that this was about forty per cent. of the cost of operating by horses for the same mileage, and under the same conditions. My estimate was then considered altogether too liberal in favor of electricity. Without going into details, I may state that the most reliable possible records of roads, under every possible condition of service, bear out the claims that I then made as to the economical operation by electricity. I have the records of only a portion of the roads which we have equipped. Some roads see fit to make public these records. Others, and with a good show of reason, do not care to do so, because of the feeling that municipal bodies, in considering the granting of franchises, will not look at the increased cost of investment, but ignoring the manifold advantages to be gained by the introduction of electricity, for the public as well as for the company, are inclined to make unreasonable demands in the way of the reduction of fares, or require unnecessary and unprofitable extensions of lines. They forget that the reduction of one cent in a fare means a cut of twenty per cent. in the receipts of the company, and that a very remarkable saving of expenses must be made in order to meet this reduction of revenue, especially where there is an increased equipment on which interest must be earned. But suffice it to say that careful investigation will convince any candid man that the economic claim has been entirely supported, and the best evidence of it is in the rapid adoption of this method of propulsion.

A few remarks may be in place relating to the interferences with other established interests which this new application of electricity has developed. Such conflicts, as electricity is applied to different industries, necessarily arise and result from the claims made by two or three enterprises to the same area of occupancy, whether of air or earth.

* * * * * * * * * * * *

The use of the grounded circuit has unquestionably interfered with another and widespread application of the use of electricity, and that is the operation of telephones which likewise use the grounded circuit. So long as electric railways were in an experimental stage, running perhaps in suburban districts, out of the way of telephone circuits, little or no attention was paid by telephone companies to their existence. The strides which have been made in the past two years and a half, bringing the railway system into the very heart of towns and cities, and into the forefront as a commercial enterprise, and the rapid increase in the extent and use of the telephone system, have brought the two interests in direct conflict, which conflict is solely because of their common use of that great reservoir of electricity, if we choose so to term it, or rather that great common medium for conducting it which has been used alike by railways, telephones and telegraphs since these industries were started.

The claim of the telephone companies, in brief, is that by right of prior ccupation and of their vested interests, no electric railway or other circuit hall so use the earth if interfering with their lines in any way. Their claim s far-reaching; it is of the broadest possible character, and, strictly interpreted, s an exclusive claim on the use of the earth for transmitting energy by elecricity. That there is an interference with the telephone circuits by an electric ilway circuit is undeniable, and the interference is one which is annoying. The haracter of the interference is twofold. Part of the trouble arises from inducon, that sympathetic response in the telephone circuit to any changes in the ectrical condition of the railway circuit, and part to leakage, caused by the verting through the telephone system of a part of the current which has en discharged into the earth and is on its way back to the central station.

* * * * * * * * * * *

We desire, of course, that it should return by the rails, but no boundary n be placed upon it. A part of it goes through the rails, but some portions ill go through the earth, through water ways, mineral veins, gas and water nnections, electric light tubes, telephone circuits, rivers and canals, and, in ct, over any and all paths which offer it opportunity to return to the source om which it originated. The shortest geographical line between two points ay be a thousand feet. The path of the current between those two points may anything from a thousand feet to fifty thousand or more. But precisely as e rail current is thus disseminated or diffused in its return paths, so also is e telephone current. True, it is only a current of small capacity, so small as interfere with no other enterprise or translating device except others of like aracter, but its diffusion is of precisely the same character and over the same rritory and through the same classes of conductors as that of the rail curnt. Could the telephone current be limited in its path, and the claim of the lephone company be narrowed down to a specific section of earth then, posbly, there might be some basis for a claim to the use of that section; but ch a restriction is, of course, manifestly impossible. Hence, any claim the lephone interest makes to the earth must be vague; it must be all-reaching; it ust be exclusive. It would seem that it has no more legal right to make a aim which prohibits a railway in the town in which the telephone circuits are erated from using the earth, than it has to make a claim that a railway in ny other city with which the telephone may be remotely connected, shall be rohibited likewise from using the earth in that particular city, although it may e a hundred miles off. It is a well-known fact among electricians, and probably o better known than among the telephone people themselves, that perfectly dependent of railway enterprises, a far better service can be rendered the atrons of the telephone where a complete metallic circuit is used, and the use f the earth abolished. The telephone is the most jealous detector possible of ll disturbances of electrical condition on the circuit which includes it. Its very unction as a transmitter of speech depends upon this marvelous delicacy. As ow operated in the majority of telephone exchanges, it is subject to continual nterference, not only from the railway circuit but from every electric light, ower or telegraph with which it is brought into proximity. It is subjected o interference from atmospheric changes and discharges. The telephone ciruits themselves interfere with each other. Cross talk and false signaling re common. Almost all these troubles can be avoided, and the telephone service ade far more perfect by using either the individual metallic return, with the witchboard properly constructed for it, or the individual return, the return ires coming to a common terminus, which would make absolutely no change in he telephonic switchboard; or what has become known as the McClure device, he use of an artificial metallic ground or common metallic return—that is, by reaking the ground connections of the individual telephones and connecting em all to one common copper return of a resistance which shall be low comared with the resistance of the instruments themselves. The lower the restance of this common return the less any interference of the telephones with ch other. The cost of this latter method is a bagatelle. It should be put up telephone companies for the sake of their patrons, independent of whatever other electrical enterprise they may be brought in contact with. Wherever intelligently put up the relief from outside interference has been almost absolute, and the testimony of parties who made complaint when telephone companies first sought to obtain an injunction against the railways is now emphatic as to the relief which has been obtained by this change in the method of running the telephone circuits. It is unquestionable that the telephone company is waging the warfare from the standpoint of economy, pleading the rights of vested interests, notwithstanding every telephone expert knows the great advantage to be gained from the metallic circuit, and notwithstanding the fact that sundry papers read at the telephone conventions not only admit that the metallic circuit is best, but give testimony from the exchange superintendents that wherever their patrons once use the metallic circuit and long distance telephone, they are never satisfied thereafter to use the grounded circuit. It is likewise suggestive that the Bell Telephone Co. to-day advertises no less than about 150 local stations in New York City equipped with the long-distance telephone and the metallic circuit. Since there is not an electric railway in the city of New York, their action in this locality could not have been dictated by interference from that interest.

The position, from a legal standpoint, seems to be something as follows: As between telephone and electric light and power companies there may be a question concerning respective rights, because the electric light and the telephone companies may both occupy the highway, as of equal dignity. But even in such a case neither one of the interests can have just right to an injunction, because the proper way of redress is a suit at law to determine the amount of damages for which the one party is liable on account of a violation of the other's rights permanent injunction being granted, I believe, only where the troubles are irremediable, or where the damage cannot be readily computed. Wherever the telephone, however, seeks to trammel electric railways in their free use of the public highway, and especially where they have been granted the right of such use, an entirely different question is presented. The public highway was originally and primarily dedicated to public travel whether by foot, by horse or by vehicle, and for no other purpose. It was contended some years ago that street railways ought not to be allowed upon highways because they had tracks; but wherever courts have been called upon to make a decision, it has been held that street railways were but an improvement upon the old methods of travel. It was even at one time questioned whether there might not be a distinction between the rights of a street railway, where the public owned the fee, and those in which the title was in private individuals, but even this distinction was not allowed. When electric railways were developed, an attempt was made to claim that they were a perversion of the highway; but it was then held that electric railways were an improvement only upon street railways propelled by horses or other motive power, and should occupy the highways with the same rights as were enjoyed by the street railways using the other motive power before electric propulsion was resorted to.

Since both the telephone and the railway companies occupy public streets by public license, it is of course necessary to examine into the source of their respective titles and the character of their occupancy, because otherwise it would be impossible to understand what are their respective rights. The electric railway has proven a great advance upon any method of street car propulsion hitherto known. It has been shown to be economical, safe and advantageous as a method of public travel. It certainly cannot be said to be objectionable *per se*. It interferes less with the travelers upon the highway than many other methods of propulsion, and its very extended adoption shows us that it has been sanctioned by public authorities as a safe and proper method of travel. The single trolley system being used by nine-tenths of the street railways in the United States using electric motive power, as against all other methods, certainly shows that practical experience is in favor of that particular method. As an improvement upon the method of propulsion it would seem that an electric street railway uses a public highway, occupies the same and enjoys the right of travel thereon, as of equal dignity with any or all other persons or

Standard of Motive Power in America 1870–1890

Original Positive and Negative Trolley in Mansfield, Ohio, 1887

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vehicles upon that highway, and that this right of enjoyment is within the original purpose for which the highways were opened. On the other hand, it is pertinent to inquire what right or title a telephone company has in the street. By virtue of the original dedication of the highway they have no rights except that of toleration. Telephones and telegraphs are identical in contemplation of law and have been held to be an additional burden upon highways. In almost every case where this question has come up in the matter of telegraphs, such has been the decision. The statutes under which telephone or telegraph lines are permitted to be erected on highways provide that while they may be so erected, the poles and wires shall not interfere with public travel upon the highways. Since this is true, the telephone companies are upon a public road not by virtue of right, but of toleration; not as the equals of the street railway, but subordinate to it. They occupy a secondary position, and this being the case, where conflict arises between the two, it would seem that the telephone interest must eventually yield, for its claim against any competitive enterprise is nothing less than a claim to the exclusive right of the earth, not to some section of it, because there are no limits to which the telephone wires may not reach, no boundaries to the portions of the earth which form a part of their circuits. Certainly no statute gives an exclusive privilege to a telegraph or a telephone company; and any claim for such an exclusive right, to be substantiated, must show an express or implied grant from some source, and the boundary as well as the source of that title. Not only this, but it must show that the title is exclusive. In view of the fact that the telegraph companies had used ground circuits for thirty years or more before the telephone was discovered, and that patents were refused for such use, it will be somewhat difficult for the telephone company to show the source of its title, and it is manifestly impossible to show the limits of the territory from which any other enterprise must be excluded, so that it will in no way interfere with the operation of the telephone system, for the telephone circuits being attached to the gas and water systems of the community in which it is located, the ramifications of such systems and of all the subterranean electric conductors of the earth in contact with these metallic conductors are unknown to science. How other electric currents entering the earth may do without invading the charmed area of the telephone and disturbing its grounded wires no man can say, much less can the telephone people themselves. The boundaries, then, of their claim being so vague, it would seem that their claim itself must necessarily fail.

Within the past two years there have been, I believe, eight attempts made by the telephone interests to get an injunction. The first was in Akron, O., in the latter part of 1888, where the Central Union Telephone Co., of Chicago, attempted to restrain one of the Sprague roads by injunction. This was denied. The next suit was against the Harrisburg road and the Sprague Co. by the Penn Telephone Co. A number of common stockholders, I believe, were interested in both companies, and although the attorneys of the railway companies were fully prepared and desirous of seeing the case brought to trial, the case was abandoned and compromised for the very sensible reason that it would cost less on both sides to compromise than to carry it to the higher courts. The next attempt on the part of the telephone interests was in the application for an injunction against one of our roads at Chattanooga, Tenn. This injunction was denied. Then came a conflict in Salt Lake City, where many of the people were so interested that they said as between the telephone and electric railway interests if the decision was against the railway company they would abolish the use of the telephone. Such heroic measures apparently were unnecessary, for the injunction was twice denied. Then application for an injunction was made in Cincinnati and this will probably become a cause celebre for an injunction—on what ground I do not yet know—was granted and the case will be carried to the higher courts.

In Eau Claire, Wisconsin, an attack was made on the railway interests under cover of a State law, which the telephone companies had quietly gotten passed requiring a return insulated conductor for any circuit carrying electric energy. The injunction was there denied, for the telephone company had somewhat overreached itself, and found itself quite as much in the mud as the railway company might be in the mire, so far as the law was concerned, because they were themselves the carriers of electric energy and were using grounded circuits, and consequently had no standing before the court. The last case with which we have been directly concerned is one at St. Joseph, which has not yet been tried. In Albany, where another electric railway company is operating, the telephone interest has succeeded in getting a temporary injunction. I believe this case, in which my own company is not particularly interested, except sympathetically, has been recently reheard and a decision on the merits is now pending.

With the records thus given it would seem that the electric railway companies have little to fear from the attacks made upon them by the Bell Telephone Co. They are well within their right, and that being so, their position must sooner or later be established beyond all peradventure. The cases which I have enumerated are not the only cases in which there have been interferences between the electric railway and the telephone; but in almost all others, both the railway and telephone companies have recognized each other's moral, if not legal, rights. Often the same stockholders have been in both companies and a sensible compromise has been effected, in which the telephone company has sometimes changed the route of its circuits, or put up a common return, or the companies have used each other's poles, and a just division of expenses has been settled upon. This would seem to me to be the better plan wherever conflicting interests arise, and is one which I would recommend in all cases where the telephone companies are willing to recognize the justice of the legal position of the railway company instead of attempting, as they have in the cases mentioned, to deny that right. A just compromise, but no surrender, should be the motto of the railway company.

So much for street car practice, and looking forward we naturally ask what will be the near future of the application of this remarkable agent? Already we have gone from one car units to trains of two, three and even four cars in the street, and four cars have been operated from a single station. The next step will be the operation of some of the cable roads, then systems like the Underground of London, the elevated railways of New York, the Brooklyn Bridge system, and then suburban lines will be operated. But is this the limit?

I have been frequently asked whether, in my opinion, electricity will ever be used on trunk lines for through passenger or freight traffic? My answer is: Probably not, according to present notions of trunk line transportation, and not by present methods of train dispatching. But in these qualifications I admit my hope and expectation of rapid transit under certain conditions.

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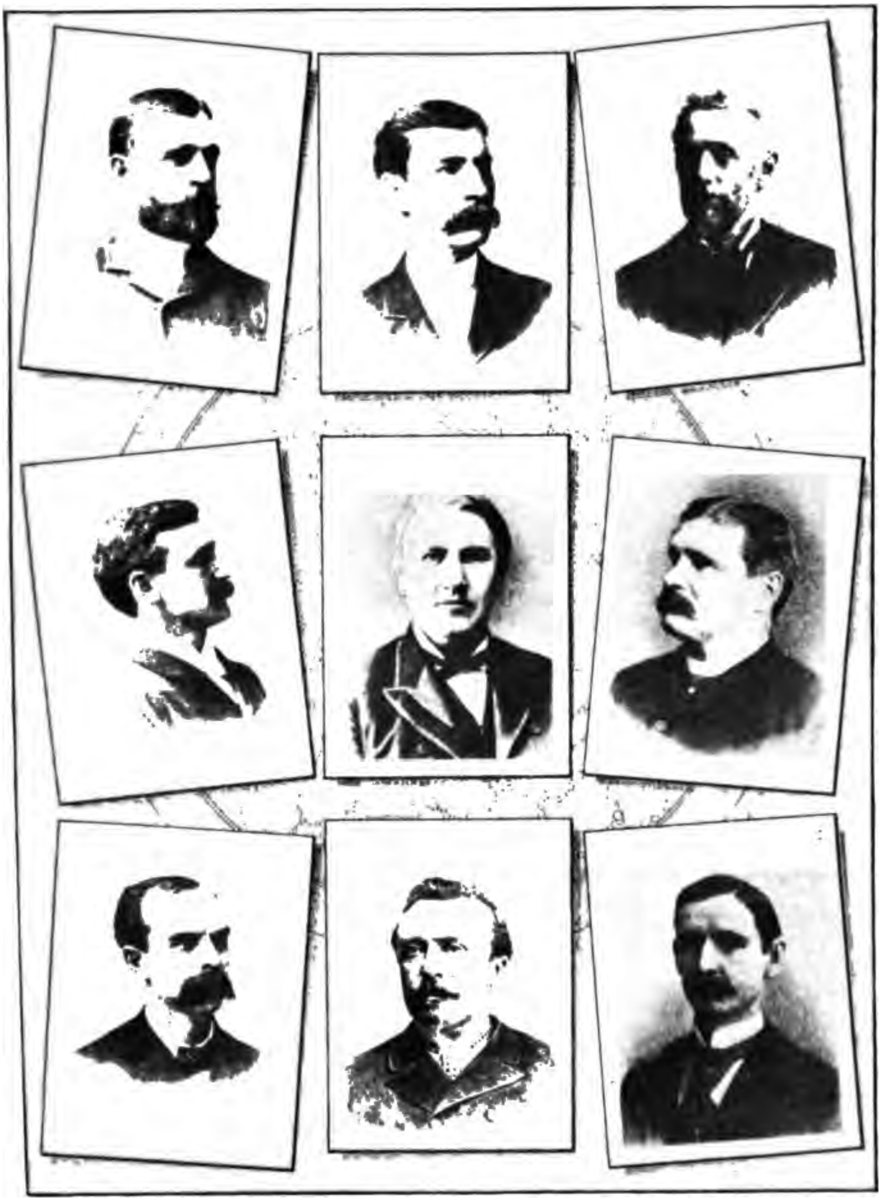

E. M. Bentley.
W. H. Knight.
J. C. Henry,

F. J. Sprague.
T. A. Edison.
C. J. Van Depoele.

Leo Daft.
S. D. Field.
S. H. Short

(The Street Railway Journal, Vol. X, No. 2, 1894)

(Reprinted by E. E. Brownell, September 1, 1919)

TH [illegible] RK
PUB [illegible] RY
A [illegible] OX
THE [illegible] NS

LIST OF THOMSON-HOUSTON ELECTRIC RAILWAYS

April 16, 1890

ROADS UNDER CONTRACT

Location	Name of Road	No. of motor cars	Length of track in miles
Attleboro, Mass.......	Attleboro, No. Att. & Wrentham St. Ry.	5	6.50
Auburn, N. Y.........	Auburn Electric Railway Co............	3	3
Albany, N. Y..........	The Albany Railway Co................	32	14
Augusta, Me.	Augusta, Hallowell & Gardiner Ry. Co...	3	3
Boston, Mass.	West End Street Railway Co.	130	18
Brooklyn, N. Y.......	Coney Island & Brooklyn R. R. Co.....	12	116
Bremen, Germany....	Bremen Tramway Co.	6	2
Dallas, Texas.........	North Dallas Circuit Ry. Co...........	4	3.80
Fort Worth, Texas....	North Side Railway Co.	15	15
Gloucester, Mass......	Gloucester Street Railway Co.	3	5
Indianapolis, Ind......	Citizens' Street Ry. Co.	10	6.50
Knoxville, Tenn......	Knoxville Street Railroad Co.	5	3.10
Kearney, Neb.........	Kearney Electric Railway Co...........	2	8
Lynn, Mass...........	Belt Line Railway Co.	4	4.50
Milwaukee, Wis.......	Milwaukee Cable Co.	12	15
New Bedford, Mass...	Union City St. Ry. Co.................	5	3
Newton, Mass........	Newton Street Railway Co..............	10	8
Passaic, N. J..........	Passaic Street Railway Co..............	3	3
Portland, Oregon.....	Woodstock & Waverly Electric Co......	4	5.25
Pueblo, Col...........	Pueblo City Ry. Co.	10	21
Port Townsend, W....	Port Townsend Street Railway Co......	3	3
Redbank, N. J.	Redbank & Seabright Railway Co.......	3	3
Rockford, Ill..........	Rockford Street Ry. Co.................	7	6.75
Shreveport, La........	Shreveport Ry. & Lamp Imp. Co........	4	5.25
Salem, Mass..........	Naumkeag Street Railway Co...........	6	3
San Jose, Cal.........	San Jose & Santa Clara R. R. Co.......	6	9
Saratoga Springs, N. Y.	Saratoga Electric Railway Co...........	2	2.50
Salem, Ohio..........	Salem City Railway Co.	3	2
South Bend, Ind......	South Bend & Mishawaka St. Ry. Co....	6	8
Springfield, Mass.....	Springfield Street Ry. Co..............	6	2
St. Louis, Mo.........	Union Depot Railway Co.	30	12.50
Springfield, Ill........	Springfield City Ry. Co.................	8	7
Toledo, Ohio..........	Toledo Electric Ry. Co..................	25	17
Toronto, Ont.	Metropolitan Street Railway Co........	2	2.75
Utica, N. Y...........	Utica Belt Line Railway	25	20
Vancouver, B. C.......	Vancouver El. Ry. & Light Co..........	4	3.50
Washington, D. C.....	Georgetown & Tenallytown St. Ry. Co.	6	6
Winona, Minn........	Winona City Railway Co.	5	4
West Superior, Wis....	Douglas County Street Railway Co......	2	4
	39 roads	431	385.20

COMPARISON, ROADS IN OPERATION

	No. of motor cars	Length of track in miles	No. of roads
April 1, 1890..................................	665	463.56	61
December 15, 1889.............................	528	335.75	49
Increase..	137	127.81	12

The grand total of roads built and under contract is 100 roads 1,096 cars and 848.76 miles of track.

The company have also received "repeat" orders as follows from roads in operation: Second Avenue Passenger Railway, Pittsburgh, 10 motors; Bangor, Me., Street Railway Co., 10 motors; Central Railway Co., Peoria, Ill., 12 motors; Des Moines, Ia., Electric Railway Co., 20 motors; Denver, Col., Tramway Co., 4 motors.

LIST OF SPRAGUE ELECTRIC RAILWAYS

Railways.	No. of Motor Cars.
Akron, O., Electric	24
Asheville, N. C., Electric	8
Atlantic City, N. J., Electric	17
Augusta, Ga., Street	16
Baltimore, Md., North Ave., Electric	1
Bay Ridge, Md., Electric	2
Berlin, Germany, Exper. Elekt. Eisenb der Allgem. Elek. Ges	3
Binghamton, N. Y., Washington Street Asylum and Park	4
Binghamton, N. Y., Street	24
Brockton, Mass., East Side, Street	4
Brooklyn & Jamaica, N. Y., Street	4
Buffalo, N, Y., Street	4
Canton, O., Street	10
Chattanooga, Tenn., Electric	16
Chicago, Ill., Cicero & Proviso	12
Cincinnati, O., Incline	20
Cleveland, O., Broadway and Newburgh, Street	24
Cleveland, O., East Cleveland, Street	75
Colorado Springs, Col., El Paso Rapid Transit Co	18
Council Bluffs, Ia., Omaha & Council Bluffs	2
Dallas, Tex., Rapid Transit	3
Davenport Ia., Central	6
Davenport, Ia., Electric	4
Dayton, O., and Soldier's Home	2
Denver, Col., So. Denver, Cable	2
Denver, Col., University Park	3
Denver, Col., Colfax Ave., Electric	4
Des Moines, Ia., Electric	2
Detroit, Mich., Rouge River and Dearborn	5
Dubuque, Ia., Elec. Ry. Lt. & Power Co	12
Dubuque, Ia., Key City Electric	2
Eau Claire, Wis., Eau Claire Street	6
Elgin, Ill., Elgin City	9
Erie, Pa., Electric Motor Co.	21
Florence, Italy, Firenzi and Fiesole	12
Fort Worth, Tex., Arlington Heights	3
East Harrisburgh, Pa., Pass.	11
Hartford, Conn. and Weathersfield	4
Kearney, Neb., Electric	2
Lafayette, Ind., Electric	9
Laredo, Tex., Imp't Co	7
Lexington, Ky., Pass. & Belt	10
Long Island City & Newton Ry., N. Y	2
Los Angeles, Cal., Electric Rapid Transit	10
Marlboro, Mass., Street	6
Milwaukee, Wis., West Side, Street	19
Minneapolis, Minn., Street	100
Moline, Ill., Electric	2
Nashville, Tenn., South Nashville, Street	10
Nashville, Tenn., Nashville & Edgefield, Street	10
Newark, O. & Granville, St.	1
Omaha, Neb, Street	87
Paducah, Ky., Street	9
Piqua, O., Electric	4
Pittsburgh, Pa., Federal St. & Pleasant Valley Pass.	45
Plattsmouth, Neb., Electric	2
Portland, Ore., Metropolitan Street	18
Portland, Or., Multnomah Street	10
Portland, Or., Wilamette Bridge	6
Quincy, Ill., Horse Ry. & Carrying Co	8
East Reading, Pa., Pass	6
Reading, Pa., Neversink Mt. Ry. Co	4
Richmond, Va., Union Pass.	42
Salem, Mass., Naumkeag St.	6
Salem-Winston, N. C., Elec.	7
Salem, Ore., Capital City	2
Salt Lake City	35
Scranton, Pa., People's St.	20
Sedalia, Mo., Street	4
Sherman, Tex., College Park Electric Belt Line	5
Sioux City, Ia., Street	20
Sioux Falls, So. Dak., So. Dakota Rapid Transit & Ry. Co	3
Sterling, Ills., Union Elec.	7
Steubenville, O., Elec. St.	8
Stillwater, Minn., Street	4
St. Joseph, Mo., People's St.	18
St. Paul, Minn., Street	30
St. Joseph, Mo., Union Pass.	30
St. Joseph, Mo., Wyatt Park Ry. Extension	18
St. Louis, Mo., Lindell	80
Tacoma, Wash., Street	56
Tokio, Japan, Exhibition	2
Troy, N. Y., & Lansingburg.	24
Utica, N. Y., & Mohawk	5
West Bay City, Mich., St.	12
Wilkesbarre, Pa., & Suburban	6
Wilkesbarre, Pa., & West Side	3
Wilmington City, Del., Elec.	10
Youngstown, O., Elec. St.	6

Making a total of 1,238 motor cars.

(The Electrical Engineer, April 16, 1890)

FIRST U. S. GOVERNMENT REPORT ON STREET RAILWAYS

Year ending July 1, 1890

OFFICIAL STREET RAILWAY STATISTICS

An Advance Report and Epitome of the Result of the Census Bureau. These Figures Will Bear Careful Study by Every Reader

The development of street railways during the decade lying between the Tenth and Eleventh Censuses—a development both as to facilities and amount of business done—may certainly be counted as one of the most remarkable features of the whole comprehensive business of transportation. Looking first to the question of length, it is found that in 1880 there were 2,050 miles of street railways in operation, while in 1890 this number had risen to 5,783 miles, an increase in the ten years of 3,733 miles. This increase, remarkable as it is for the whole ten years, is still more remarkable when the decade is divided into two periods of 5 years each, for then it is seen that the most astonishing development has been during the last half of the ten years and at a rate before unparalleled. The figures show that during the first five years the increase of mileage was 888 miles, while during the last half it was 2,845 miles. Looking for the cause of this extraordinary increase it can readily be found in the introduction of electric roads. These roads, which in June 30, 1890, constituted nearly one-fifth of the number of street railways, were none of them in operation previous to the year 1886. In that year two electric railways were beginning to operate; in 1887 the number had increased to 6; in 1888 to 30; and in 1889 to 57, while during the first six months of 1890 no fewer than 49 new electric roads were reported for. The development of cable road has also largely assisted in this increased mileage, but not nearly to such an extent as the electric railway, while, as has been shown, the year 1886 was the year of inception of the electric road, the first cable railway beginning to run in 1877. The increase by years is shown in the following table:

YEARS	Total Length (Miles)	Increase	
		Miles	Per Cent
Ten Years		3,733.31	182.10
1880	2,050.16	......	......
1881	2,150.09	99.93	4.87
1882	2,342.20	192.11	8.93
1883	2,506.14	163.94	7.00
1884	2,680.31	174.17	6.95
1885	2,938.29	257.98	9.63
1886	3,268.58	330.29	11.24
1887	3,890.22	621.64	19.02
1888	4,499.49	609.27	15.66
1889	5,285.11	785.62	17.46
1890 (6 months)	5,783.47	498.36	9.43

Looking to the urban locality of increase it is found that the most remarkable is in the smaller cities, a fact that is plainly illustrated in the following tables:

ITEMS	Length of Street Railways (Miles)		Factor of Increase
	1890	1880	
All cities	5,783.47	2,050.16	2.82
Cities of more than 50,000 inhabitants	3,205.59	1,584.16	2.02
Cities of less than 50,000 inhabitants	2,577.88	466.00	5.53

When the final computations were made it was found that on July 1, 1890, the street railway companies of the United States in independent operation numbered 789 and that these, repeating the previous figures, carried on their operations over 5,783 miles of street line, or over a total track length of 8,123 miles. On this length of line 32,505 passenger cars were in use; the roads and equipment cost all told $389,357,289, they gave employment to 70,764 men, and carried the astonishing total of 2,023,010,202 passengers. A good idea of the extent of this traffic may be realized when it is stated that the street railways of the United States carried last year a number of passengers considerably greater than the population of the globe, and when it is also stated that the steam railways of the United States with all their 157,759 miles of line and 25,665 passenger cars only carried during the same year 472,171,343 passengers, or 1,550,838,859 passengers less than were carried by the street railways.

The increase by geographical divisions will be seen by the following table:

Geographical Divisions	Length of Line		Increase	
	1890	1880	Miles	Per Cent
The United States	5,783.47	2,050.16	3,733.31	182.10
North Atlantic	2,063.94	1,035.60	1,028.34	99.30
South Atlantic	465.93	135.96	329.97	242.70
North Central	1,867.93	508.46	1,359.47	267.37
South Central	773.05	242.63	530.42	218.61
Western	612.62	127.51	485.11	380.45

It will be noticed that the Western Division shows the greatest per cent of increase and the Northern Central the next, although the two Southern Divisions display a rapidity of construction which is in keeping with the other forms of development marking this section of the country.

Dealing somewhat more with particulars, the 27 principal cities of the United States are next taken up and their increase shown:

CITIES	Length of Line		Increase	
	1890	1880	Miles	Per Cent
Baltimore	100.57	46.54	54.03	116.09
Boston, Lynn and Cambridge	237.83	95.56	142.27	148.88
Brooklyn	173.24	111.65	61.59	55.16
Buffalo	44.30	25.44	18.86	74.14
Chicago	193.11	80.47	112.64	139.98
Cincinnati	67.90	48.13	19.71	40.93
Cleveland	88.38	26.41	61.97	234.65
Denver	79.12	8.00	71.12	389.00
Detroit	59.25	26.55	32.69	123.08
Indianapolis	45.00	15.00	30.00	200.00
Jersey City and Hoboken	46.65	15.40	31.25	202.92
Kansas City	69.42	9.50	59.92	630.74
Louisville	84.42	39.25	45.17	115.08
Milwaukee	52.75	11.41	41.34	362.31
Minneapolis	58.00	9.00	49.00	544.44
Newark and Elizabeth	62.59	37.54	25.05	66.73
New Orleans	112.59	81.89	30.70	37.49
New York	180.56	130.55	50.01	38.31
Omaha	51.50	4.50	47.00	1,044.44
Philadelphia	276.94	258.17	18.77	7.27
Pittsburgh and Allegheny	65.95	38.63	27.32	70.72
Providence	44.95	35.30	9.65	27.34
Rochester	35.83	13.02	22.81	175.19
St. Louis	115.25	63.29	51.96	82.10
St. Paul	25.27	6.00	19.27	321.17
San Francisco	89.11	57.08	32.03	56.11
Washington, D. C.	45.22	29.47	15.75	53.44

The western cities again show the largest percentage of increase, but Boston and its neighborhood show the greatest absolute increase and Chicago is second. The reason for Philadelphia's remarkable length of line lies in the fact that this is street length, it being a peculiarity of that city, and in some degree of the Boston roads, that the tracks usually occupy different streets in going to and from a terminus, instead of being laid upon the same street. The result is that roads in these two cities traverse a greater length of street in proportion to track length than in New York, Brooklyn and Chicago. The difference between the two calculations can be seen in the following table, showing **street** length of line and **track** length of these five cities:

CITIES	Street Length of Line	Track Length
Philadelphia	273.94	390.33
Boston, Lynn and Cambridge	237.83	377.42
Chicago	193.11	365.76
New York	180.56	351.53
Brooklyn	178.24	351.12

Still keeping to the same 27 principal cities, the preceding statistics of cars, employes, passengers and cost are to be distributed as follows:

CITIES	No. of Cars	No. of Emp'y's.	No. of Passengers Carried in One Year	Total Cost
Baltimore	490	1,547	40,659,982	$6,709,450.39
Boston, Lynn and Cambridge	2,396	4,188	129,038,563	17,604,671.76
Brooklyn	2,862	6,359	147.500,399	17,711,765.51
Buffalo	219	730	16,685,983	2,012,541.46
Chicago	3,657	5,796	180,326,470	26,943,443.78
Cincinnati	561	1,213	37,905,370	8,056,031.64
Cleveland	730	1,650	39,164,773	7,156,027.89
Denver	461	866	21,535,735	7,518,400.14
Detroit	296	772	22,791,566	2,370,197.61
Indianapolis	205	482	9,833,000	1,683,765.13
Jersey City and Hoboken	317	880	24,115,322	2,629,759.62
Kansas City	652	1,376	38,000,978	12,344,487.44
Louisville	429	746	21,281,584	3,713,078.88
Milwaukee	248	622	14,512,156	4,208,956.24
Minneapolis	324	616	14,648,529	3,836,233.60
Newark and Elizabeth	244	525	20,068,884	3,282,381.75
New Orleans	527	876	30,510,662	5,978,464.89
New York	3,503	12,778	449,647,853	99,294,071.24
Omaha	200	469	11,900,000	6,500,000.00
Philadelphia	1,368	4,136	165,117,627	15,746,376.03
Pittsburg and Allegheny	378	1,529	46,099,227	10,077,053.83
Providence	349	787	18,473.722	2,080,068.76
Rochester	392	510	11,372,596	6,615,586.46
St. Louis	1,369	2,501	67,800,252	10,716,195.77
St. Paul	227	433	11,245,805	2,653,585.54
San Francisco	988	2,398	80,619,005	17,239,933.24
Washington, D. C.	451	1,112	31,032,187	3,552,659.95

Turning next to motive power the following division of statistics is decidedly interesting:

ITEMS	All Motive Powers	Distribution			
		Animal	Electric	Cable	Steam
Length of line	5,783.47	4,061.94	914.25	283.22	524.06
Length of all tracks	8,123.02	5,661.44	1,261.97	486.31	711.30
Number of cars	32,505	22,408	2,895	5,039	2,113
Number of employes	70,764	44,314	6,619	11,673	8,158
Number of passengers	2,023,010,202	1,227,756,815	134,905,994	373,492,708	286,854,685
Total cost	$389,357,288.37	$195,121,682.50	$35,830,949.63	$76,346,618.23	$82,058,038.51

Perhaps the most notable feature of the above table is the fact that in 1890 the railways operated by animal power were still far ahead of all others as regards their gross operating statistics. Rapid as was the advance of electric and cable roads during the latter five years of the decade, only a beginning was made in the supplanting of the older form of motive power. It is interesting also to see that although both in number and length of lines the electric railways have far outstripped the cable railways, the latter nevertheless represent twice as great an investment, operate nearly twice the number of cars and do a business more than twice as great. These relative figures point clearly to the far greater density of traffic upon the cable lines and to their large first cost. The cable lines almost without exception operate in the denser portions of large cities, while the greater part of the electric roads are either suburban or serve the people of comparatively small cities.

The following table which gives a summary of the capital stock, funded debt, dividends and interest, while it cannot be implicitly relied on as showing the condition of every road, may be accepted as being sufficiently correct and indicative for all practical purposes. The year's report ends July 1, 1890.

ITEMS	Capital Stock Issued and Outstanding	Dividends Declared
All motive powers	$163,506,544.50	$11,600,334.54
Animal	62,415,615.50	4,390,519.54
Electric	4,034,900.00	225,697.00
Cable	6,437,900.00	653,587.00
Steam	25,917,180.00	1,561,512.00
Mixed and inseparable	64,700,950.00	4,769,019.00

ITEMS	Rate of Dividends Declared	Funded Debt Issued Outstanding
	Per Cent	
All motive powers	7.09	$103,494,259.99
Animal	7.03	34,361,904.99
Electric	5.59	3,230,300.00
Cable	10.15	4,076,000.00
Steam	6.03	19,326,200.00
Mixed and inseparable	7.37	42,499,855.00

ITEMS	Interest Accrued	Rate of Interest Paid
		Per Cent
All motive powers	$5,870,710.72	5.67
Animal	1,997,664.92	5.81
Electric	187,505.00	5.80
Cable	218,160.00	5.35
Steam	1,181,512.00	6.11
Mixed and inseparable	2,285,868.80	5.33

The receipts and expenditures of all the street railways have been summarized as follows:

ITEMS	All Motive Powers	Animal	Electric	Cable	Steam	Mixed and Inseparable
RECEIPTS						
Grand total	$91,721,844 74	$38,403,748 32	$3,220,396 33	$3,798,414 36	$12,709,627 93	$33,589,657 50
From Operation—						
Total	90,617,210 71	37,866,930 79	3,215,268 38	3,771,801 78	12,541,249 61	33,221,960 15
Passengers	89,711,829 39	37,536,924 08	3,125,871 49	3,718,541 80	12,464,962 10	32,865,529 92
Other sources	905,381 32	330,006 71	89,396 89	53,259 98	76,287 51	356,430 23
Rentals and miscellaneous	1,104,634 03	536,817 83	5,127 95	26,612 58	168,378 32	367,697 35
EXPENDITURES						
Grand total	87,388,006 65	37,063,110 78	2,994,802 27	3,476,075 55	11,700,492 06	32,150,525 99
Operating expenses	62,011,184 93	27,893,077 33	2,266,422 02	2,477,624 34	7,192,671 91	22,181,389 33
Fixed Charges—						
Total	13,978,902 88	4,700,649 25	450,551 05	564,497 95	2,939,075 36	5,324,129 27
Rentals	2,561,342 50	615,232 01	19,436 55	1,525 30	288,631 00	1,636,517 64
Taxes and licenses	3,308,190 49	1,674,457 77	59,060 99	77,282 65	501,447 31	995,941 82
Interest	8,086,215 99	2,403,730 36	371,865 51	485,690 00	2,148,997 05	2,675,927 07
Miscellaneous	23,153 90	7,323 16	188 00	....	....	15,742 74
Payment from Net Income—						
Dividends	10,180,726 12	4,039,165 90	188,928 22	333,587 00	1,561,512 00	4,057,533 00
Miscellaneous	1,217,192 72	433,218 30	88,900 98	100,366 26	7,232 79	587,474 39
Total surplus for period	5,400,299 07	1,866,194 59	381,980 35	420,335 03	1,167,980 43	1,563,808 67
Total deficit for period	1,066,460 98	528,556 75	156,386 29	97,996 22	158,844 56	124,677 16
Net surplus for period	4,333,838 09	1,337,637 84	225,594 06	322,338 81	1,009,135 87	1,489,131 51

Ending July 1, 1890

In conclusion the balance sheet of 81 per cent of the operating roads will be found in the subjoined tables:

ITEMS	All Motive Powers	Animal	Electric	Cable	Steam	Mixed and Inseparable
ASSETS						
Cost of road and equipments...	$315,547,761 38	$121,283,492 18	$7,840,482 49	$15,353,698 21	$66,319,165 49	$104,750,922 01
Other permanent investments..	46,830,823 07	5,920,962 22	357,309 23	410,646 48	21,781,166 54	18,360,738 60
Value and franchise...........	14,597,444 00	4,842,362 40	1,225,000 00	1,192,581 60	20,000 00	7,317,500 00
Bills and accounts receivable...	7,538,199 98	1,877,493 47	46,666 67	24,453 05	3,488,918 53	2,100,668 26
Cash on hand	7,774,860 61	4,064,015 98	186,323 25	82,524 56	1,030,295 21	2,411,701 61
Supplies	2,157,292 37	801,314 45	31,724 75	73,261 64	346,130 64	904,860 89
Miscellaneous assets	10,418,987 83	1,783,546 33	870,033 43	857,035 13	2,151,117 59	4,757,255 35
Profit and loss (deficits).......	3,610,082 15	2,281,954 35	116,055 94	467,358 34	345,222 91	399,490 61
Total	$408,475,451 39	$142,855,142 38	$10,673,595 76	$18,461,559 01	$95,482,016 91	$141,003,137 33
LIABILITIES						
Capital stock	$211,277,798 08	$77,492,738 29	$5,702,687 67	$8,775,854 53	$44,465,533 34	$74,840,984 25
Funded debt	151,872,289 01	49,226,234 01	3,486,200 00	5,584,500 00	44,369,000 00	49,206,355 00
Bills and accounts payable.....	16,325,347 08	4,926,246 03	1,163,022 84	299,653 41	1,525,841 55	8,410,583 25
Interest due	1,013,780 48	379,986 01	18,120 05	21,712 50	290,619 41	303,342 51
Dividends due	191,119 25	51,008 31	405 78	....	45,268 90	94,435 76
Miscellaneous liabilities	12,838,213 52	3,366,366 04	156,284 27	2,754,730 59	2,674,488 79	4,886,348 83
Profit and loss (surpluses).....	14,956,898 97	8,412,563 19	146,875 15	1,025,107 98	2,111,264 92	3,261,087 73
Total	$408,475,451 39	$142,855,142 38	$10,673,595 76	$18,461,559 01	$95,482,016 91	$141,003,137 33

The 81 per cent of the street railroads referred to above is all that gave any satisfactory statement in the form of a balance sheet, but it includes most of the important companies, and calculations to fill out the 100 per cent, can readily be made.

Ending July 1, 1890

Copper Prices in New York

Highest, lowest and average yearly prices of Lake Copper in New York from 1860 to 1917, inclusive.

Year	Highest	Lowest	Average	Average
1860	$24.00	$19.75	$22.87½	
1861	27.00	17.50	22.25	
1862	32.87½	20.75	21.87½	
1863	38.75	29.00	33.87½	
*1864	55.00	39.00	47.00	
1865	50.50	28.00	39.25	
1866	42.00	26.50	34.25	
1867	29.25	21.50	25.37½	
1868	24.50	21.50	23.00	
1869	27.00	21.50	24.25	$29.40
1870	23.37½	19.00	21.19	
1871	27.00	21.25	24.12½	
1872	44.00	27.12½	35.56	
1873	35.00	21.00	28.00	
1874	25.00	19.00	22.00	
1875	23.87½	21.50	22.69	
1876	23.25	18.75	21.00	
1877	20.50	17.50	19.00	
1878	17.62½	15.50	16.56	
1879	21.75	15.50	18.62½	22.87
1880	25.00	17.87½	21.50	
1881	20.37½	16.00	18.25	
1882	20.37½	17.87½	18.50	
1883	18.12½	14.87½	15.87½	
1884	15.00	11.00	13.75	
1885	11.50	9.75	11.10	
1886	12.12½	10.00	11.00	
1887	17.75	9.12½	11.25	
1888	17.50	15.75	16.80	
1889	17.50	11.00	13.75	15.17
1890	17.25	14.00	15.75	
1891	15.00	10.25	12.87½	
1892	12.37½	10.50	11.50	
1893	12.50	9.62½	10.65	
†1894	10.25	9.00	9.43	
1895	12.75	9.25	10.70	
1896	11.75	9.75	10.92½	
1897	12.00	10.75	11.30	
1898	12.87½	10.87½	12.01	
1899	19.50	13.00	17.75	12.28
1900	17.25	16.00	16.70	
1901	17.00	13.00	16.77	
1902	13.50	11.00	12.14	
1903	15.37½	12.00	13.72	
1904	15.37½	12.00	13.24	
1905	20.00	14.87½	16.09	
1906	25.00	18.37½	19.87	
1907	26.25	12.50	21.30	
1908	14.62½	12.62½	13.50	
1909	14.62½	12.75	13.39	15.67
1910	14.00	12.50	13.12	
1911	14.37½	12.20	12.71	
1912	17.80	14.15	16.58	
1913	17.75	14.50	15.70	
1914	15.50	11.30	13.61	
1915	23.00	13.00	17.64	
1916	35.00	23.00	28.17	
1917	36.00	23.50	29.18	14.67

Average for 58 years—$18.98.

*Highest price. †Lowest price.

HISTORY OF ELECTRIC RAILWAYS

(The Engineering Record, February 7, 1891, Page 153)

Dr. Clarence E. Woodman, lecturing at the Catholic University at Washington, D. C., last week, said that it will probably never be known who was the first to conceive the possibility of electrical propulsion of vehicles.

As soon as Ampere, Arago and Faraday had given the results of their experiments to the world, a host of inventors arose with machines to apply them. Twelve years after the memorable experiment of Faraday, a poor blacksmith of Branoon, Vermont, Thomas Davenport, applied electricity to mechanical uses, and among them the propulsion of cars on tracks. It is worthy of note that at that time ordinary street cars had hardly been thought of. In 1834 Davenport exhibited in Springfield, Mass., an electrical engine which traversed a circular track, and this was probably the first electric railway in the world. Between 1835 and 1841 this extraordinary genius constructed more than 100 successfully working electric motors, scarcely any two of which were of the same design, and which varied in size from a small model up to an engine capable of driving a rotary printing press for twelve consecutive hours. In 1840 he published a weekly newspaper, which was printed on a press driven by one of his electro-magnetic engines.

In 1847, Moses Farmer, of Connecticut, exhibited a motor capable of drawing a car containing two passengers. In 1839, Robert Davidson, a Scotchman, succeeded even better and brought out a motor which propelled a 16-foot car four miles an hour. In 1850, Dr. Charles Grafton B. Page, of Salem, Mass., produced a still larger and more powerful electro motor. Next came Thomas Hall, a workman of Dr. Page's who built a model of an electric locomotive that took its electricity from the rails.

But the credit of priority in the invention of the electric railway in its present form, that is, with a moving motor on the car connected by electric conductors to a stationary dynamo machine, is, the lecturer said, undoubtedly due to Stephen D. Field, a nephew of Cyrus Field, who gave us the Atlantic cable. His experiments were carried on from 1877 to 1880. In the early part of 1880, Mr. Edison constructed a road some 90 rods in length and ran on it a large-sized electric locomotive.

In 1883, Leo Daft equipped the Saratoga and Mt. McGregor Railroad with an electric system. On this line an ordinary steam railway car was used and 100 passengers at a time were carried. Dr. Woodman concluded with a description of several systems of transporting packages by electricity, especially Professor Jenkins' telpherage system.

PHILADELPHIA RAILWAY ELECTRIFICATION

(The Engineering Record, May 7, 1892, Page 375)

Engineers' Club of Philadelphia.—A regular meeting was held April 16, President Christie in the chair, and about 75 persons present. The proposed extensive conversion of street railways now operated in Philadelphia by animal power to electric lines is a prime topic of public interest in that city, and the discussion of the evening was therefore an informal consideration of the merits and demerits of the trolley system of electric traction. The discussion took a wide range; covering the danger to human life from power and lighting currents and the hazard of fires. Mr. F. R. Ford said an electric road with wooden poles, with the rails bonded for the return circuit and with construction otherwise of the cheapest may be built for $1,000 a mile, while with iron poles, 125 feet apart on each side of the street, with span wire crossing at each pair of poles, and with feeder wires on one set of poles, etc., the cost may reach $5,000 per mile. For feeder wires underground in wooden troughs, we must add $3,000 per mile of single track, and this will give the most perfect electric railway now known. Mr. Carl Hering said there are two principal objections to the conduit system. The first is the cost. The system in Buda-Pesth cost $20,000 per mile, and would have cost $35,000 here. Once down, however, the cost of maintenance is less than that of other systems. The other objection is that the conduit fills with water, but this may, of course, be drained away. Among the systems tried at Birmingham, the electric accumulator system is the cheapest under ordinary circumstances, and horse cars are the dearest. The cable is the cheapest for heavy traffic on heavy grades. The discussion was continued to the next meeting, and the club adjourned to lunch.

ANNUAL STATEMENTS OF MASSACHUSETTS RAILWAYS

(Street Railway Review, December, 1892, Page 705)

The state railroad commission of the Bay State publishes the status of the following principal railways:

The Lynn and Boston

Total income, $619,266; total expense, $522,679; dividend, 8 per cent, $52,000; total surplus Sept. 30, 1892, $100,594.

Newton Railway

Total income, $62,866; total expenses, $40,225; dividend, 7 per cent, $9,450; surplus, $11,763.

Union, New Bedford

Total income, $169,471; total expenses, $130,490; dividend, 5 per cent, $12,996.

Brockton

Total income, $143,560; total expenses, $99,963; dividend, 6 per cent, $11,904; surplus Sept. 30, 1892, $24,576.

Boston and Revere Electric

Total income, $6,568; total expenses, $6,174; surplus, $390.

Worcester Consolidated

Total income, $318,472; total expenses, $255,495; dividend, 2 per cent quarterly, $28,000; surplus, $37,959.

Springfield

Total income, $333,550; total expenses, $201,601; dividend, 8 per cent, $44,000; surplus, Sept. 30, $37,877.

West End, Boston

Total income, $6,317,205; total expenses, $4,477,783; dividends, $1,323,360.

Lowell

Total income, $212,570; total expense, $182,423; dividend, 6 and 3 per cent, $27.000.

FARES, PER CAPITA IN CANADIAN CITIES

(Street Railway Review, November, 1893, Page 699)

A very interesting feature of the published reports of the Canadian street railways is made evident in the following little table, taking the population according to the last census and the patronage for one year, as per the September reports:

	Population	St. Ry. Receipts	Fares per Capita
Toronto	181,220	$815,212	$4.49
Montreal	216,650	750,754	3.47
Ottawa	44,154	130,000	2.94

The average was $3.63 per capita for the three cities. Toronto is the largest city as regards area, hence the apparent discrepancy in fares per head.

This year's receipts for Montreal show $186,357 in excess of previous years, which were under horse regime.

ROCHESTER'S RAILWAY REPORT

(Street Railway Review, November, 1893, Page 699)

A statement of the business of the Rochester, N. Y., Street Railway Company from July 1, 1892, to July 1, 1893, shows a gratifying increase in gross earnings and a correspondingly fair decrease in expenses of operation.

The gross earnings from operation for the past year were $798,761, an increase of $115,403 over 1892. The operating expenses were $430,082, a decrease of $12,943. Thus the net earnings from operation were $368,678, an increase of $102,460 over last year. Advertising privileges paid $5,087 and rents $1,490, which with dividends on stocks owned by the company amounting to $10,487, gives a gross income from all sources of $385,744, an increase of $114,324 over 1892. The net income was from all sources $150,000, an increase of $68,364. The per cent of operating expenses to earnings was 61 in 1892 and 54 in 1893.

There are now 75 miles of city track, all laid in the past four years. One hundred and fifty motor cars and eighty trailers are now in use, and 450 men are on the pay roll of the company.

INCREASE OF MILEAGE IN TEN YEARS

(Street Railway Review, January, 1892, Page 15)

In 1880 there were in the United States 2,050 miles of street car tracks; in 1890 there were 5,783 miles; an increase of 3,733 miles in 10 years, of which 888 miles were built from 1880 to 1885, and 2,845 miles from 1885 to 1890, inclusive. This phenomenal increase has been largely due to electric roads of which there were two in 1886, six in 1887, thirty in 1888, fifty-seven in 1889 and nearly 400 in 1891.

AMERICAN STREET RAILWAY SYSTEMS SERVING FROM 25,000 TO 35,000 POPULATION.	1890.		1892.	
	Horse.	E. C. M.	Horse.	E. C. M.
PASSENGER INCOME PER CAPITA.				
No. of roads not reporting	....	....	1	4
" " earning less than $1.50 per capita	2	....	....	....
" " " from $1.50 to $2.00 per capita	2	1	1	1
" " " " 2.00 " 2.50 "	2	1	1	1
" " " " 2.50 " 3.00 "	....	....	....	....
" " " " 3.00 " 3.50 "	1	1	....	2
" " " " 3.50 " 4.00 "	3	...	1	...
" " " " 4.00 " 4.50 "	....	1	1	....
" " " " 4.50 " 5.00 "	....	....	....	1
OPERATING EXPENSES PER CAR MILE.				
No. of roads not reporting	1	2	2	8
" " operating at less than 10 cents per car mile	1	2	....	....
" " " from 10 to 15 cents per car mile	2	....	....	....
" " " " 15 " 20 " "	2	....	....	1
" " " " 20 " 25 " "	2	....	1	1
" " " " 25 " 30 " "	2	....	1	....
PERCENTAGE OF OPERATING EXPENSES.				
No. of roads not reporting	....	1	1	4
" " operating at less than 60 % of pass. income	....	1	....	1
" " " from 60 to 65 % of pass. income	....		....	....
" " " " 65 " 70 % " "	....	1		....
" " " " 70 " 75 % " "	1	1	....	4
" " " " 75 " 80 % " "	1	....	1	1
" " " " 80 " 85 % " "	7	....	....	...
" " " " 85 " 90 % " "	...		2	....
" " " " 90 " 95 % " "	1	....	....	....
NET EARNINGS.				
No. of roads not reporting	....	1	1	
" " earning less than $7,500 net	2	..	..	....
" " " from $7,500 to $10,000 net	1	....	1	....
" " " " 10,000 " 15,000 "	1	....	....	....
" " " " 15,000 " 20,000 "	1	....	1	1
" " " " 20,000 " 30,000 "	5	2	....	2
" " " " 30,000 " 40,000 "	....	...	1	2
" " " " 40,000 " 50,000 "	....	....	....	1
" " " over 50,000	1	....	....	....
PERCENTAGE OF NET EARNINGS TO CAPITAL LIABILITIES.				
No. of roads not reporting	....	1	1	4
" " earning less than 2½ % on capital liabilities	1	....	....	1
" " " from 2½ to 5 % " "	2	2	....	1
" " " " 5 " 7½ % " "	3	....	1	2
" " " " 7½ " 10 % " "	1	....	1	....
" " " " 10 " 12½ % " "	1	1	1	1
" " " " 12½ " 15 % " "	2	....	....	1

(The Street Railway Journal, March, 1894, Page 169)

HOURS AND WAGES IN OHIO

(Street Railway Review, January, 1893, Page 56)

The bureau of labor statistics, of the State of Ohio, of which W. T. Lewis is commissioner and Thomas Thomas is chief clerk, are compiling a rpeort on street railway employes. To the courtesy of Mr. Thomas we are indebted for the following table. These figures are for the fiscal year ending July 1, 1892, and are returns from 43 companies operating in the State. No reduction in wages has since been reported by any road, but there were 27 advances, ranging from 5 to 40 per cent, mostly for drivers, conductors and motormen. The table does not include the advances.

Number of Roads, 43

	Number of Employes	Aver. Hrs. of Labor per Day	Average Wages per Day
Conductors (electric cars)	803	11.2	$1.82
Conductors (horse cars)	313	11.4	1.85
Conductors (cable cars)	67	10.	1.75
Drivers	468	11.5	1.69
Motormen	941	11.2	1.80
Trolleymen	77	11.1	1.58
Linemen	60	11.1	2.10
Laborers	307	10.	1.46
Motor repairers	153	10.5	2.01
Motor inspectors	21	11.6	1.87
Shedmen	21	11.7	1.57
Car cleaners	110	11.8	1.60
Lamp tenders	14	11.	1.55
Watchmen	51	10.7	1.60
Engineers	62	11.13	2.55
Firemen	54	11.4	1.70
Oilers	38	12.0	1.68
Dynamo tenders	13	11.7	1.91
Feeders	29	11.	1.53
Grooms	241	10.5	1.45
Farriers	13	10.5	2.40
Harness repairers	6	10.	1.71
Woodworkers	90	10.	2.21
Blacksmiths	75	10.1	2.08
Painters	36	10.	2.17
Cashiers	36	9.4	2.10
Not Classified	69		
Total	4,168		

ORIGINAL ELECTRIC STREET RAILWAY ENGINEERS

The pioneer American engineers were Messrs. Thomas A. Edison, S. D. Field, Bentley and Knight, Leo Daft, John C. Henry, Charles J. Van Depoele, S. H. Short, F. E. Fisher, Frank J. Sprague, W. M. Schlesinger and C. F. Adams from 1884 to 1888, on the three electric systems of distribution, i. e., electric conduit (underground system), double trolley and single trolley overhead systems.

Following the year of 1888, the Thomson and Houston Company and others joined in the construction of this new public utility industry, which for rapid growth and invested capital, as a public service corporation, surpassed anything of its kind in the history of the world.

SOURCES OF DIRECT CURRENT FOR ELECTRIC STREET RAILWAYS

When the electric street railway came into existence, it had to compete with animal, steam and cable systems of transportation, these ranking in the order given, in their aggregated receipts, as well as in importance.

The year of 1886 was, in reality, the qualification period of the electric street railway, as a common carrier.

Therefore, we find the electric street railway engineers and (if they might be called as such) promoters, in 1886, decidedly divided as to whether to use the storage battery on the cars (Julien Storage Battery System), or the Double or Single trolley system of overhead wires, or some re-constructed plan to electrify the old cable roads.

The source of electrical energy and its distributing features had them in an endless uncertain state for several years. They did not know which one was going to be the better, for the proper propulsion of the electric street cars, in order to make it a success.

The overhead "Double" and "Single Trolley" systems were being constructed in about equal proportions in 1886-7.

This divided opinion, as to the use of the storage battery or either of the overhead trolley systems, continued on for many years following the introduction of the electric street railway industry.

In the City of Milwaukee, Wis., this same question came up, in 1889, so that on August 9, 1889, the Common Council of the City of

Milwaukee authorized a committee to go East and investigate the various electric street railway modes of operation and construction. They made an actual investigation of the Julien Electric Storage Battery system, the Sprague and the Thomson and Houston overhead trolley systems.

This committee recommended the overhead wire system, as the best electric street railway system for the City of Milwaukee, and to authorize its construction upon the various street railways seeking authority from the City of Milwaukee. (See pages 21 to 25, inclusive, in the Compilation Section of this report for details of the Committee's report.)

As a consequence, the overhead trolley system was adopted for the three important street railways, as authorized by the Common Councils of the City of Milwaukee, passed October 14, 1889, and accepted by the Milwaukee City Railroad Company, the Cream City Railroad Company and the West Side Railroad Company.

FAILURE OF CABLE ROADS AS ELECTRIC CONDUIT SYSTEMS

There is an angle of this subject, which at this time, should not be passed unnoticed. This was the attempt to reconstruct the old cable street railways into some sort of an electric street railway traction system. Cleveland, Ohio, being one of the first to change.

Particular stress was laid upon the cable roads, especially by the Eastern municipalities, in an attempt to prevent them from placing any overhead wires upon the streets, which was necessary in the construction of either the Double or Single overhead trolley system.

Even the capitalists, who were very heavily interested in the cable roads, did everything conceivable to prevent the most costly part of their physical property being consigned to the scrap heap. Many efforts were made to employ part of the cable road construction for the new electric traction system, but it was all in vain.

All the cable roads in the United States were eventually changed to the overhead trolley electric street railway construction. Not a single exception has been recorded, or is known of today. The present Metropolitan Street Railway system (surface lines) in the City of New York, N. Y., finally became a "Double Trolley" underground (insulated) electric conduit system by reconstruction, in part, of some of the old cable roads in New York City.

CONDUIT SYSTEM IN WASHINGTON, D. C.

Before passing the cable roads, a few words about the conditions in Washington, D. C., may be found interesting.

In the latter part of September, 1895, what remained of the overhead single trolley system in Washington was changed to the "Double Trolley," underground, electric conduit street railway system. (See the Compilation Section of this report for particulars.)

On September 30, 1897, the cable powerhouse of the Capital Traction Company was destroyed by fire. On resumption of operation, the cable road routes were soon electrified by the installation of the Double Trolley, underground, electric conduit street railway system. (See the Compilation Section of this report for full detailed information.)

(Street Railway Journal, April, 1899)

(Year 1898)

Gross Receipts Per Capita and Per Mile of Track in the Principal American Cities

The accompanying table has been carefully compiled, with a view to showing the comparative patronage by the peoples of the principal cities of the United States of their street railway systems. The table covers the population served, the miles of track, the gross receipts, the gross re-

NAME OF CITY.	STREET RAILWAY SYSTEMS.					
	Population Served.	Number Included.	Miles of Track.	Gross Receipts.	Gross Receipts Per Mile Track.	Gross Receipts Per Capita.
New York City—						
Manhattan and Bronx.				$	$	$
Elevated Lines.....	2,156,000	1	109	9,183,542	84,252	4.26
Surface Lines......		8	368	16,044,332	43,597	7.44
Total............		9	477	25,227,874	52,910	11.70
Brooklyn.						
Elevated Lines*f*....	1,197,000	3	75	2,481,730	33,090	2.07
Surface Lines......		4	412	8,522,142	20,684	7.12
Total............		7	487	11,003,872	22,597	9.19
Queens.						
Surface Lines.........	128,000	..	92	491,969	5,347	3.86
Richmond.						
Surface Lines.........	65,000	..	59	293,004	4,966	4.51
New York City.		..	1,115	37,016,719	....	....
Elevated Lines......	3,546,000	..	184	11,665,272	63,397	3.29
Surface Lines.......		..	931	25,351,447	27,229	7.14
Total............		16	1,115	37,016,719	33,199	10.44
Chicago—						
Elevated Lines.....	1,875,000	3	70	2,766,982	39,529	1.48
Surface Lines......		7	625	12,347,121	19,739	6.59
Total............		10	695	15,114,103	21,747	8.06

(Street Railway Journal, April, 1899)
(Year 1898)

NAME OF CITY.	STREET RAILWAY SYSTEMS.					
	Population Served.	Number Included.	Miles of Track.	Gross Receipts.	Gross Receipts Per Mile Track.	Gross Receipts Per Capita.
Philadelphia	1,250,000	3	484	11,452,999	23,663	9.16
Eastern Massachusetts	1,250,000	39	894	12,330,666	13.793	9.86
Boston	*a* 788,000	3	349	9,106,108	26,091	11.56
St. Louis	*a* 675,000	10	302	5,836,242	19,324	8.65
Eastern New Jersey	*d* 603,000	11	400	4,863,897	10,216	8.07
Baltimore	600,000	1	354	4,020,900	11,357	6.70
Pittsburg—Allegheny	*ad* 528,000	15	390	4,351,694	11,160	8.24
Cleveland and Suburbs	520,000	7	330	3,386,000	10,261	6.51
Minneapolis—St. Paul	*a* 405,000	1	230	2,145,000	9,327	5.30
Cleveland City	400,000	2	204	2,927,000	14,348	7.31
Buffalo and Suburbs	400,000	14	300	2,276,546	7,590	5.69
Detroit	365,000	2	163	1,597,666	9,803	4.38
San Francisco	350,000	7	273	4,841,284	17,733	13.83
Lynn	*e* 319,000	1	154	1,431,936	9,299	4.49
New Orleans	309,000	7	187	2,219,089	11,867	7.40
Milwaukee	*a* 280,000	1	158	1,761,500	11,152	6.29
Providence	*a* 280,000	1	140	1,776,695	12,693	6.34
Washington	*b* 275,000	10	178	2,198,277	12,348	7.99
Louisville	*a* 275,000	1	140	1,297,394	9,264	4.72
Montreal	250,000	1	85	1,342,368	15,792	5.37
Troy—Albany	*a* 224,000	4	94	1,198,047	12,745	5.35
Kansas City, Mo	*c* 200,000	1	136	1,942,852	14,287	9.72
Indianapolis	*c* 194,000	1	100	978,964	9,790	5.05
Rochester	*a* 190,000	3	105	835,190	7,954	4.40
Toronto	180,000	1	110	1,210,618	11,000	6.73
Denver	167,000	..	..	....	....	7.50
Toledo	*c* 145,000	1	99	921,998	9,313	6.35
Worcester	*a* 138,000	3	96	761,520	7,932	5.52
Columbus, O.	*c* 135,000	1	64	680,173	10,628	5.04
Syracuse	130,000	3	61	482,243	7,905	3.71
Scranton	125,000	1	35	383,727	10,963	3.07
Albany	*a* 124,000	2	49	647,943	13,222	5.23
Atlanta	123,000	2	85	497,733	5,855	4.04
Fall River	102,000	1	34	306,115	9,003	3.00
Richmond	100,000	2	66	561,906	8,514	5.62
Nashville	*c* 100,000	1	47	493,186	10,493	4.93
Troy	*a* 100,000	2	45	550,104	12,224	5.50

a Including suburbs reached by street railway lines whose gross receipts are given. *b* Estimated. *c* Principal system. *d* Population partly estimated. *e* Comprising populations of twenty-one cities and towns tributary to the cities of Lynn and Boston. *f* Including receipts, mileage, etc., of New York and Brooklyn Bridge.

ceipts per mile of track, and the gross receipts per capita served.

(Street Railway Journal, April, 1899)
(Year 1898)

The largest gross receipts per capita are obtained by the street railway systems in the following cities and groups:

	Population.	Gross receipts per capita.
San Francisco	350,000	$13.83
New York (Manhattan and Bronx)	2,156,000	11.70
Boston (and immediate suburbs)	788,000	11.56
Greater New York	3,546,000	10.44
Eastern Massachusetts	1,250,000	9.86
Kansas City (principal system)	200,000	9.72
Philadelphia	1,197,000	9.16
New York (Brooklyn Borough)	1,250,000	9.19
St. Louis	675,000	8.65
Pittsburg-Allegheny	528,000	8.24
Eastern New Jersey	603,000	8.07
Chicago	1,875,000	8.06

The largest gross receipts per mile of track are shown by the systems in the following cities and groups:

New York (Manhattan and the Bronx)	$52,910
New York (complete)	33,199
Boston	26,091
Philadelphia	23,663
New York (Brooklyn Borough)	22,597
St. Louis	19,324
San Francisco	17,733
Montreal	15,792
Eastern New Jersey	10,216

Strange to say, New York city, though by far the largest in the country, does not lead the list in point of gross receipts per capita, but this honor is reserved for San Francisco, which shows $13.83 percapita.

GROSS RECEIPTS PER MILE OF TRACK PER ANNUM

On the 43 Different Electric Street Railway Systems for the Year of 1898

Richmond (Borough) surface line	$ 4,966
Queens (Borough) surface lines	5,347
Atlanta, Georgia	5,855
Buffalo, N. Y., and suburbs	7,590
Syracuse, New York	7,905
Worcester, Massachusetts	7,932
Rochester, New York	7,954
Richmond, Virginia	8,514
Fall River, Massachusetts	9,003
Louisville, Kentucky	9,264
Lynn, Massachusetts	9,299
Toledo, Ohio	9,313
Minneapolis and St Paul, Minnesota	9,327
Indianapolis, Indiana	9,790
Detroit, Michigan	9,803
Newark and Eastern New Jersey. On 11 lines	10,216
Cleveland, Ohio, and suburbs	10,261
Nashville, Tennessee	10,493
Columbus, Ohio	10,628
Scranton, Pennsylvania	10,963
Toronto, Canada	11,000
Milwaukee, Wisconsin	11,152
Pittsburgh and Allegheny City, Pennsylvania	11,160
Baltimore, Maryland	11,357
New Orleans, Louisiana	11,867
Troy, New York	12,224
Washington, D. C.	12,348
Providence, Rhode Island	12,693
Troy and Albany, New York (combined)	12,745
Albany, New York	13,222
Eastern Massachusetts. 39 lines (Boston excluded)	13,793
Kansas City, Missouri	14,287
Cleveland, Ohio	14,348
Montreal, Canada	15,792
San Francisco, California	17,733
St. Louis, Missouri	19,324
Chicago, Illinois (surface lines)	19,739
Brooklyn, New York (surface lines)	20,684
Philadelphia, Pennsylvania	23,633
Boston, Massachusetts	26,091
Brooklyn, New York (3 elevated lines)	33.090
Chicago, Illinois (3 elevated lines)	39,529
New York City (Manhattan and 8 Bronx surface lines)	43,597
New York City (Manhattan and Bronx Elevated lines)	84,252

RECAPITULATION

Milwaukee, Wis., year of 1898	$11,152
Milwaukee, Wis., year of 1910	$26,756
Milwaukee, Wis., year of 1917	$27,460

Milwaukee, Wis., year of 1888 (3 horse car lines)	$12,164

ELECTRIC STREET RAILWAY STATISTICS IN 43 AMERICAN CITIES

RE-COMPILED BY E. E. BROWNELL
SEPTEMBER 1, 1910

Location	Population	Track	Gross Receipts Per Capita
Fall River, Mass.	102,000	34	$ 3.00
Scranton, Penna.	125,000	35	3.07
Syracuse, N.Y.	130,000	61	3.71
Queens, Long Island	128,000	92	3.86
Atlanta, Ga.	123,000	85	4.04
Detroit, Mich.	365,000	163	4.38
Rochester, N. Y.	190,000	105	4.40
Lynn, Mass.	319,000	154	4.49
Richmond, Staten Island	65,000	59	4.51
Louisville, Ky.	275,000	140	4.72
Nashville, Tenn.	100,000	47	4.93
Columbus, Ohio	135,000	64	5.04
Indianapolis, Ind.	194,000	100	5.05
Albany, N.Y.	124,000	49	5.23
Minneapolis-St.Paul	405,000	230	5.30
Troy-Albany, N.Y.	224,000	94	5.35
Montreal, Canada	250,000	85	5.37
Troy, N. Y.	100,000	45	5.50
Worcester, Mass.	138,000	96	5.52
Richmond, Vir.	100,000	66	5.62
Buffalo & Suburbs	400,000	300	5.69
Milwaukee, Wis.	280,000	158	6.20
Providence, R. I.	280,000	140	6.34
Toledo, Ohio	145,000	99	6.35
Cleveland & Suburbs	520,000	330	6.51
Baltimore, Md.	600,000	354	6.70
Toronto, Canada	180,000	110	6.73
Cleveland City	400,000	204	7.31
New Orleans, La.	300,000	187	7.40
Denver, Colo.	167,000	---	7.50
Washington, D. C.	275,000	178	7.99
Chicago, Ills.	1,875,000	695	8.06
Eastern New Jersey	603,000	400	8.07
Pittsburgh-Allegheny, Penna	528,000	390	8.24
St. Louis, Mo.	675,000	302	8.65
Philadelphia, Penna.	1,250,000	484	9.16
Brooklyn, N.Y.	1,197,000	487	9.19
Kansas City, Mo.	200,000	136	9.72
Eastern Massachusetts	1,250,000	894	9.86
New York City	3,546,000	1,115	10.44
Boston, Mass.	788,000	349	11.5
N.Y.City,Manhattan-Bronx	2,156,000	477	11.7
San Francisco, Cal.	,350,000	273	

1898

UNITED STATES GOVERNMENT REPORT

STEAM AND ELECTRIC RAILWAY STATISTICS SUMMARIZED.

Statistics from government reports	Steam railroads 1907.	Electric railways 1907.	Ratio electric to steam.
Passengers carried	873,905,133	9,533,080,766	10 900
Rides per inhabitant per year	9	90	10 000
Total car mileage	29,652,000,000	1,618,343,584	.054
Receipts from passengers	$564,606,342	$382,132,494	.677
Income from freight	1,936,000,000	7,438,582	.004
Income from operation	2,649,731,911	429,744,254	.162
Operating expenses	1,749,164,649	251,309,252	.143
Net earnings	900,567,262	178,435,002	.200
Taxes and fixed charges	420,717,658	138,094,716	.325
Net income	479,849,604	40,343,286	.084
Dividends	227,394,962	25,558,857	.113
Surplus	252,454,642	14,781,429	.059
Capitalization, at par	18,885,000,000	3,774,000,000	.200
Total mileage	327,975	34,404[1]	.105
Passenger cars	43,973	70,016	1.600
Freight cars, etc	1,991,557	13,625	.007
Total cars	2,126,594	84,000	.040
Locomotives	51,891	117[2]	.007
Motor cars	....	68,874	....
Horse-power capacity	5,000,000	2,475,000	.490

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[1] The mileage of electric railways in 1911 is about 36,000 miles.

[2] The number of electric locomotives in 1911 is about 430.

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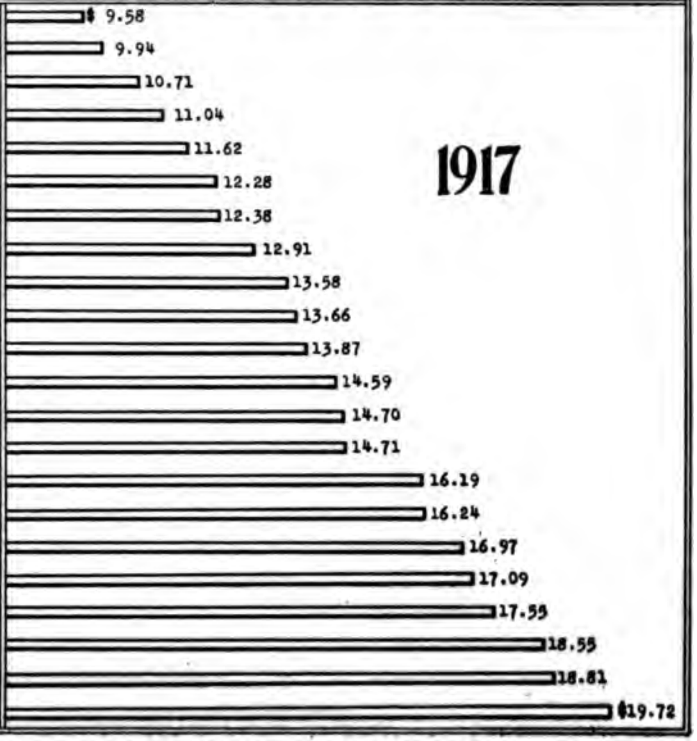
ELECTRIC STREET RAILWAY STATISTICS IN 22 AMERICAN CITIES ENDING JULY 1, 1917

(COMPILED BY B. E. BROWNELL SEPTEMBER 1, 1919)

No.	Location	Population	Cars		Amount Paid Per Capita Per Annum
1	Grand Rapids, Mich.	133,000	149	11	$ 9.58
2	Columbus, Ohio	220,000	349	16	9.94
3	Milwaukee, Wis.	445,000	561	13	10.71
4	Lincoln, Neb.	47,000	91	19	11.04
5	Denver, Colo.	268,000	436	16	11.62
6	Seattle, Wash.	366,000	687	19	12.28
7	New Orleans, La.	377,000	624	17	12.38
8	Indianapolis, Ind.	283,000	533	19	12.91
9	Toronto, Canada	463,000	927	20	13.58
10	Louisville, Ky.	240,000	630	26	13.66
11	Cincinnati, Ohio	414,000	1,310	32	13.87
12	Washington, D. C.	369,000	1,317	36	14.59
13	Des Moines, Iowa	104,000	167	16	14.70
14	Cleveland, Ohio	692,000	1,477	21	14.71
15	Minneapolis-St.Paul	625,000	1,100	18	16.19
16	Omaha-Council Bluffs	209,000	482	23	16.24
17	Kansas City, Mo.	407,000	746	18	16.97
18	St. Louis, Mo.	768,000	1,408	18	17.09
19	Baltimore, Md.	594,000	2,073	35	17.55
20	Pittsburgh, Penna.	740,000	1,812	24	18.55
21	San Francisco, Cal.	471,000	942	20	18.81
22	Boston, Mass.	964,000	3,723	38	$19.72



Number of cars operated per unit of 10,000 persons

PART III

EARLY AND LATE MODES OF DIRECT CURRENT DISTRIBUTION APPLIABLE TO ELECTRIC STREET RAILWAYS

Mr. Thomas A. Edison, in 1880, used one of the tram rails for the positive side of the 110 volt circuit, and the other tram rail for the negative side of the electric railway circuit. Conducting his experiments first with 20 volts, then 110 volts and finally with 220 volts between the rails. The rails in most cases did not touch the earth, as a general rule.

In a short time electrolytic action developed upon the positive rail where it came in contact with the moist earth. The current leakage between the two tram rails was considerable, especially when the ground was wet from rains. (See photograph in this report indexed under "Illustrations"; also photograph in this report for type of car and locomotive used.)

This electrolytic action upon the positive rail is the first known reference to "Electrolysis" from the diverted electric currents of an electric street railway; but, only as found upon the rails in 1882, not upon subsurface metallic structures.

At the Berlin, Germany, Industrial Exhibition in 1879, a 160 volt circuit was shown, with the rails used as both sides of the circuit. (See photograph indexed under "Illustrations" of this report.

At the Paris, France, Exposition, in 1881, there was a 150 volt circuit, with an overhead trolley wire, as the positive feeder, which made it the first Single Trolley System in the world. (See photograph indexed under "Illustrations" of this report.)

The American engineers, being very much divided in opinion, used both the double and single trolley system of overhead construction.

In Asbury Park, N. J., Los Angeles, Cal., part of Detroit, Mich., Kansas City, Mo., Mansfield, Ohio, Appleton, Wis., Montgomery, Ala., Denver, Colo., part of Pittsburgh, Penna., Albany, N. Y., part of Cincinnati, Ohio, (before the telephone court case, decided on

June 2, 1891, was rendered) and several other cities had the overhead "Double Trolley" system in operation, either in part or in whole.

These double trolley installations ran from 1884 to 1890, inclusive.

In the City of Appleton, Outagamie County, Wisconsin, the Appleton Electric Street Railway Company was granted a franchise for fifty years. This franchise was dated January 1, 1885, and passed by the Appleton City Council on January 14, 1886, being retroactive.

For instance, no mention was made in this franchise as to the method to be employed for supplying the electric current to the motors upon the street cars. It must have been inferred, however, that it was intended to be an overhead "Double Trolley System." At any rate, Mr. Charles J. Van Depoele, expert engineer, made an overhead double trolley system of it, beginning with the initial construction of the road. Furthermore, the City of Appleton reserved the right to specify the motive power to be used.

The Appleton road had five electric motor cars running July, 1886, or about four (4) years before the first electric street car ran through the streets of the City of Milwaukee, which was on April 4, 1890.

In order to lessen the cost of the extensions and decrease the original cost of maintenance and operation, all of the above mentioned double trolley electric street railways, they being owned privately, abandoned the overhead double trolley systems.

In no instance did they ever consult the various municipalities before changing from the Double to the Single overhead trolley system, at least, not so far as any record or personal knowledge has shown.

These double trolley companies simply assumed the requisite authority and went ahead and made the changes. These double trolley street railway companies knew little about their own new industry, but the authorities of the municipalities, wherein they operated, knew even less, so that they could have taken almost any advantage of the municipalities without it being known.

Therefore, the same thing applied to the interpretation of the original electrical installation and construction of an electric street railway., when changing over from a cable or horse car line. This is the writer's opinion of the Milwaukee situation in 1889-90.

One point stands out very conspicuously, and that is, that the Double Trolley construction (early) was not made primarily for the purpose of preventing electrolytic corrosion upon adjacent subsurface metallic structures; although, in the year of 1889, there are several references to the theoretical possibilities of such destruction.

Actual manifestations of the corrosive action by diverted electric street railway currents, upon subsurface metallic structures, began to come to light a little in 1889, while in 1890 and 1891 the subject became a recognized fact. In 1892, there were any number of positive proofs.

In 1891 and 1892, various experiments and electrolytic surveys were made in and around the City of Boston, Mass., by I. H. Farnham, chief engineer of New England Telephone Company, and C. H. Morse of Cambridge, Mass. Mr. F. S. Pearson, chief engineer, the West Side Street Railway Company, Boston, Mass., also made interesting and practical experiments early in 1892. (First car October 10, 1887.)

The writer's first actual field experiments, on the subject began in the Summer of 1893.

In the City of Denver, Colorado, the authorized use of an electric street railway was given on February 5, 1885, and the "Double Trolley" system, under S. H. Short, expert engineer, was installed.

In Kansas City, Mo., August, 1885, John C. Henry, expert engineer, installed a 250 volt "Double Trolley System." The overhead trolley wires were strung 10 inches apart.

In the City of Cleveland, Ohio, in July, 1884, Messrs. Bentley and Knight, expert engineers, installed a "Double Trolley Electric Conduit System," but were forced to abandon it in 1885 as impractical.

THE STREET RAILWAY JOURNAL

(The Street Railway Journal, August, 1890, Page 388)

Single vs. **Double Trolley** is a suit that seems to be going by default. Since the publication of the able address on the above subject, delivered by Mr. George W. Mansfield before

> the Boston Electric Club some months since; the love of the telephone people for the double wire system seems to be on the wane. The address furnished conclusive proof to any thinking man that the double system is neither expedient nor practical. Only a few roads are now using the double system and there is little or no demand for it by the promoters of new lines. The remedies that have been tried to prevent interference with the telephone interests seem to be working satisfactorily, and on new lines that have put in very heavy ground wire properly connected with every part of the track, there seems to be no disturbing effect whatever on the telephone circuits.

In the many legal actions brought by the grounded telephc companies (from 1887 to 1891), to compel the adoption of the doul trolley overhead wire system for the single trolley overhead syste it is very striking and interesting to note, that in not a single instan in all of these cases, threatened and fought out, was there one s gle reference, deduction or word said about electrolytic action fr diverted electrical currents. This applied then to the single troll systems in use, as well as those who proposed to use them, yet a murmur came from the telephone companies protesting to the s gle trolley system.

The obvious reason of this profound silence, is that the te phone companies, at that time, had no subsurface metallic structu of their own. They were too busy, in the organization of their o monopoly, to give the municipal water departments and gas co panies any advice of that which they might readily have forese

It was only when their lead-sheath covered cables began to electrolyzed that they raised any protest.

The writer doubts, very much, as to whether there was any ov head double trolley built in the United States after the date on whi was authorized the electrification of the three (3) main street r ways of the City of Milwaukee, i. e., October 14, 1889.

The writer is convinced from strictly an engineering and ope tive viewpoint, that the single trolley system has a decided adv tage over the overhead double trolley system. There is no merit the overhead double trolley system, except as a means of protecti against electrolytic corrosion to subsurface metallic structures.

Today (1919) all electric street railway companies operati upon, over and below the streets of our American cities, use the to 650 volt, direct current, Single Trolley system in principle.

LIST OF ELECTRIC RAILWAYS USING DIRECT CURRENT IN EXCESS OF 650 VOLTS

CT CURRENT LLATIONS	PERMANENT WAY		OVERHEAD CONSTRUCTION							ROLLING STOCK								
			Trolley or Third Rail		Transmission Line			Generating Stations				Locomotives		Control				
								(1) 2000-kw. 60-25-cycle Freq. Ch. Set G.E. Pr. also pur. Gt. Western Pr. Co.		10	27					1911		
Southern Traction Co., Dallas, Texas	158	5	Catenary	1200	66,000	60	3	Power purchased from Texas Pr. & Lt. Co.	6 1 Port	22 6 Ex.	65	2	25	Full	1200 Volts	Oct. 1913	New	Dallas, Waco & Corsicana
Southwestern Traction & Pr. Co., New Iberia, La.	14	0	Catenary	1200	none			(1) 200-kw. 1200-volt d-c. Gen. Engine Driven Gen. Elec.	0	3	36.5	0	..	Half		May 1913	New	New Iberia & Jeanerette
Texas Traction Co., Dallas, Texas	78	0	Catenary	1200	33,000	60	3	Purchased from Texas Pr. & Lt. Co. also own 2400-kw. G.E. Turbine	6 1 Port	0		0				Operated at 600 Volts	600 Volts	Denison, Sherman, Dallas, McKinney
Tidewater So. Railroad Co., Stockton, Cal.	33	0	Catenary	1200	16,500	60	3	Power purchased from Sierra & San Francisco Pr. Co.	2	3	43	1	40	Half	1200 Volts	Nov. 1913	New	Stockton & Modesto
Toronto Suburban Ry., Toronto, Can.	49	3	Catenary	1500	25,000	25	3	Power purchased from Toronto Pr. Co.	3	6	52	0	..	Half	1500 Volts	Bldg. 1916	New	Toronto, Georgetown & Guelph
United Rys., Portland, Ore.	20	0	Catenary	1200	60,000	33	3	Power purchased from Portland Lt. & Pr. Co.	1	7	45	1	40	Full	1200 Volts	Jan. 1913	600 Volts, D-C.	Portland & Wilkesboro
Valparaiso & Northern Ind. Ry., Valparaiso, Ind.	46			1200	2,200	60	3	Part of Mahoning & Shenango Ry. & Lt. Co. Lines (Rp. Ry. & Lt. Prop.)	1	......		0				Operated at 600 Volts	600 Volts	Valparaiso, Chesterton & Porter
Washington, Baltimore & Annapolis Elec. R.R. Baltimore, Md.	61	14	Catenary	1200	33,000	25	3	Power purchased from Potomac Elec. Pr. Co.	4	53	45	3	45	Half	Hot Air	Feb. 1910	6600 Volts, 1φ & Steam	Washington, Baltimore & Annapolis
Waterloo, Cedar Falls & Northern, Waterloo, Iowa	60		Catenary	1400	40,000	25	3	(2) 1500-kw., (1) 3000-kw Turbine Generator	4	6 5	60	5	60	Full	Hot Water	Sept. 1914	New & 600 Volts	Waterloo & Cedar Rapids
Willamette Valley Southern Ry.	30	0	Catenary	1200	57,100	60	3	Power purchased from Portland Ry. & Light Co.	2	2	40	1	50	Full	1200 Volts	Jan. 1914	New	Oregon City, Beaver Creek, Mt. Angel
Foreign High Voltage D-C. Railways, General Electric																		
Bethlehem Chile Iron Mines Co., Tofo, Chile	15	0	Catenary	2400	2,300	60	3	(2) 3500-kw., 2300-volt Turbine Generator, General Electric	1	0	..	3	120	....	....	Bldg. 1916	New	Tofo & Iron Mines
Imperial Railways, Japan	20	4	Catenary	1200	11,000	25	3	(3) 1000-kw., 11,000-volt Gas Eng. Alternators Dick. Kerr.	1	40	48			Full		1915	Steam	Tokio, Yokohama
South Manchurian Ry., China	25	0	Catenary	1200	2,300	60	3			2	25	3	40	Half		1914	Steam	Fushun, Colliery
Victorian Rys., Melbourne, Australia	150	0	Catenary	1500	20,000	25	3	(6) 10,000-kw. Parsons Turbine	18	400	52	0	..	Half		Bldg. 1916	Steam	Melbourne & Suburbs

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The electric street railway surface lines (former Metropolitan Street Railway Company) on Manhattan Island, New York City; together with those in Washington, D. C., and Cincinnati, Ohio, are he only places where the Double Trolley System, insulated circuit, are used in any of the American cities.

Note the following quoted article bearing upon the overhead louble trolley system, as installed in the City of Havana, Cuba, in 1905.

THE ELECTRICAL WORLD,
Weekly Review of Current Progress in Electricity and its Practical Applications

(Electrical World and Engineer, August 5, 1905, Page 230)

THE DOUBLE TROLLEY IN CUBA

To the Editors of Electrical World and Engineer:

Sirs: In reference to your editorial in your issue of July 8 regarding the double-trolley system, you have been misinformed regarding the use of double trolley on the lines of this company now under construction in the vicinity of the city of Havana. While we will use two trolley wires outside of the city, they will be used in a way common to a large number of interurban roads in the States; the single-trolley method being used, with track return.

We were compelled to use the double-trolley system in Havana proper by the United States military engineers, due to their belief that this was the only method of avoiding the possibility of the danger of corrosion of the existing water works system.

In general our road will be along the lines of the usual interurban road in the States, except where changes are made necessary by local conditions.

A. W. K. BILLINGS,
Havana, Cuba. Chief Engineer Havana Central Railroad.

The Waterloo, Cedar Falls & Northern Railway Company of Waterloo, Iowa, and several other interurban electric railway companies, using the 1200 volt, direct current, overhead or third rail system of operation. (See complete list in this report.)

There are very few electric street railway companies using alternating currents of electricity and they are for interurban service.

It would, indeed, been very advantageous to the electric stre railway companies, economically and otherwise, had they original installed the single trolley systems with 1200 volts, instead of pra tically 600 volts direct current.

It would have meant, practically, about one-half of the curren in amperes, to handle. The expensive electrical conductors woul have also been reduced to about one-half their size.

Therefore, all other conditions remaining equal, there would hav been but one-half of the return current diversion to contend wit

Electrolytically speaking what an improvement this character operation have brought over present day operation.

The Wisconsin state laws are very clearly defined as to the obl gations placed upon the electric light and power companies, with r spect to injury to persons, property, etc., by reason of improp electrical insulation, inductive effects and the escape of electrici of every character and kind. (See pages 32 and 33 of the Compil tion Section of this report, which states the legal construction).

It is quite noteworthy that the Act of April 15, 1889, Chapt 375, of the Wisconsin laws, was passed 354 days before the first ele tric street railway car was started in the City of Milwaukee, or Ap 4, 1890 and six (6) months, lacking one (1) day, before the passin of the three (3) electric street railway ordinances on electrificatio or October 14, 1889.

This fact has quite an important bearing upon the Milwauk Electrolysis situation.

Ths Act of April 15, 1889, provides all of the necessary techn cal requirements for protecting the owners and operators of su surface metallic structures against electrolytic deterioration, as su tained in the following Eau Claire, Wisconsin, decision:

WISCONSIN SUPREME COURT

January 29, 1890

(*From Appeal Book)

Interference of Electric Currents—Injunction

Wisconsin Telephone Company,

vs.

Eau Claire Street Railway and
The Sprague Electric and Motor Company.

DECISION

The principal use of streets is to accommodate the traveling public and whatever rights telephone companies have to maintain their lines in streets are in subordination to the right of travel.

This principle applies not only to modes of travel in use when the rights of the telephone company were acquired, but also to new modes invented or applied generally in aid of travel.

Application for injunction at suit of telephone company to restrain an electric light company from operating its road so as to interfere, by its strong currents of electricity, with the use of the telephone system, denied, it appearing that the single trolley system used by the railroad company was the best system known, while the telephone company could avoid injury to itself by adopting the metallic circuit.

Facts stated in opinion.

Miller, Noyes & Miller, for plaintiff.

H. H. Hayden, for defendants.

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*An appeal was taken, and the case printed, from which the opinion is copied, but an agreement was reached and the appeal was never argued.

OPINION OF THE COURT

This is a motion for a temporary injunction to restrain the plaintiff from operating their electric railway in the streets of Eau Claire, for the reason, it is claimed, that the escape of electricity from the wires of defendant's road interferes with the successful operation of the telephones of the plaintiff. It is claimed by the plaintiff that the leakage of the electricity complained of is occasioned by the failure on the part of defendant to erect suitable wires for the return of the electricity, instead of allowing it to escape through the wheels of the car and thence return by the railroad track. The railroad in question was duly authorized by the city authorities, and has been in operation as a horse railway up to the present winter. The plaintiff company have operated their telephones within the city and along the streets, parallel with the street railway, for several years since 1882.

During the present winter the defendant company changed their power from animal power to electrical, and for three months past have been using the last named power.

The principal use of the street is to accommodate the traveling public, and whatever rights the telephone company have must be held to be in subordination to this right of travel. They must so conduct their business as not to interfere with ordinary travel and they must submit to any necessary inconvenience resulting from the ordinary travel passing over the street. They take their right subject to this burden. This principle applies not only to the mode of travel at the time the telephone was built and their rights acquired, but applies as well to any new or improved modes of travel which have been or may hereafter be invented and applied generally in aid of travel on the public streets.

But the plaintiff company has the right to demand that those passing along the streets, either with vehicles or with electric cars or any other mode of travel, shall exercise reasonable care. They must be guilty of no negligence; they must adopt all the usual, reasonable and necessary safeguards to prevent accident or injury to the property or rights of others. If they do this, and, notwithstanding such care, the plaintiff is subjected to inconvenience, it must be borne by it. The evidence in this case satisfies me that the defendant has been guilty of no negligence, either in the building or operation of its road.

The system adopted by the defendant is one in common use. The evidence clearly shows that what is known as the single trolley system, by which the electricity returns by way of the wheels of the car and the track, is now used by nine-tenths of the roads in operation in the United States; that the double trolley roads, which adopt the plan of the return wire, have in some instances been built; but the evidence of all the experts is to the effect that they are practical failures; and the evidence fails to show that any scheme has been invented which is practicable and can be made a success except the system adopted by the defendant in this case, that is, the single trolley system.

Hence it follows that they have been guilty of no negligence, and as it is further true that the system adopted is substantially the only one upon which roads can be operated successfully, it follows that the prayer of the complainant asking for an injunction to restrain the running of the road as it is, is, in effect, asking for the entire cessation of the use of the defendant's road, as an electric road; I am not prepared to do that.

The defendant has been subjected to considerable expense and has just got the road in successful operation without any objection as the evidence shows, on the part of the plaintiff company, and it would be a hardship now, and virtually destroy their property, to grant the injunction prayed for.

On the other hand, if I deny the motion, the telephone company can continue the use of their lines. This is amply proved by the undisputed evidence of the experts in this case. It appears beyond question that a way has been contrived by which, by means of a return wire forming a metallic circuit, they can operate their plant successfully without injury from the escape of the electricity complained of. With them it is not a question of total suspension of business, but simply a question of expense of alteration, and so far as the evidence appears, I should conclude that the expense would not be a very considerable amount. Hence the injury complained of is not irreparable or continuous. When the improvement is made, the trouble complained of will cease, and the plaintiff, if it should be found that this expense so incurred was made necessary by the wrongful act of this defendant, could sue the defendant at law and recover whatever expense was incurred in making the change. I therefore think that if the plaintiff has suffered any injury by the acts of the defendant in building or operating their road, it has a complete remedy at law.

The plaintiff claims that it is entitled to this injunction under chapter 375 of the laws of Wisconsin for the year 1889. Sections one and two of this chapter read as follows:

Section 1. It shall be the duty of each and every electric light and power company and of each and every person engaged in the transmission of electrical energy within this State to provide by suitable insulation, return wires or other means against injury to persons or property, by leakage, escape or induction of any and every current of electricity.

Section 2. Neglect of any of the above provisions shall entitle the person or corporation injured thereby to a preliminary injunction preventing further use of such current until said Section 1 has been complied with.

It appears to me that the language of this statute is broad enough to cover the case of the plaintiff as well as that of the defendant. The object of that statute is to prevent leakage of electric wires permeating the earth and causing damage to others, and by its terms as clearly forbids the plaintiff from allowing the electricity to escape into the ground as it does the defendant and hence, if I am right in this, it follows that even if the defendant was in the wrong in not providing for a safe return of the electricity, that the plaintiff is just as clearly in like position, differing only in the amount of electricity that is allowed to escape.

And the evidence in this case shows that, but for the unlawful act of the plaintiff in using the ground for a return circuit, contrary to the provisions of the statute, no serious inconvenience would result from the proximity of the defendant's wires, and the plaintiff, being in the wrong, and suffering damage, in part, by reason of its own wrongful act, is not entitled to an injunction.

SUMMARY

Therefore, from all appearances, looking carefully into the future of the electric street railway industry, it seems that the single trolley 600 volt, direct current system is to be with us for an indefinite period.

There is no necessity for changing it.

The writer sees no possibility of this system being abandoned for trackless transportation, instead of the present plan of electricity from a central point of distribution. The day of rapid progression of the urban electric street railway may have passed, but it will still hold its position, as an important factor, among public service utilities.

PART IV

ELECTRICAL DISTRIBUTION SYSTEMS OF THE MILWAUKEE ELECTRIC STREET RAILWAYS

If the reader will turn to Part II, pages 7 to 16, inclusive, of the Compilation Section of this report, he will find nine (9) various ordinances on the electrification of the street railways in the City of Milwaukee, Wis. The dates of these various ordinances range from June 14, 1886, to June 1, 1891. These street railway ordinances state and provide rules and restrictions which the street railway companies must follow in the electrifying of their respective roads.

On October 14, 1889, Ordinance No. 109 was passed by the Common Council of the City of Milwaukee, authorizing the electrification of (1) the Milwaukee City Railroad Company, (2) the Cream City Railroad Company and (3) the West Side Railroad Company.

The West Side Railroad Company started the first electric street railway car on April 4, 1890. (See pages 27 to 31, inclusive, in Compilation Section of this report for full particulars.) The Cream City Railroad Company is said to have started its first electric street car on April 30, 1890.

There is not the least doubt, in the mind of the writer, that each and every one of these electrification ordinances, from 1886 to 1891, inclusive, was intended to convey the objective purpose of installing an overhead Double Trolley System, in the City of Milwaukee.

Nevertheless, it is true, however, that these earlier nine (9) street railway ordinances did not specify, or by inference state, that the Double Trolley System of installation was for the purpose of preventing electrolytic corrosion, yet, notwithstanding all of this, no other literal construction can be drawn than that of the Double Trolley System with overhead wires. It is very clearly stated along this line.

The Appleton, Wis., street railway ordinance passed on January 14, 1886, is far less specific than the Milwaukee ordinances, yet the Appleton Electric Street Railway Company adopted the Double Trolley System of overhead wire distribution. This was also upon an entirely new electric street railway system.

Upon page 11 of the Compilation Section of this report, beginning with the fourth line from the top of the page, there will be found these words, "Should any street railway company aforesaid use, in connection with said system any supplementary or feeder wires, such supplementary or feeder wires shall be laid underground, and all wires used to conduct electric current for the purpose aforesaid shall be constructed with a return parallel circuit:"

There can be no question about the intended interpretation of this paragraph. Its intent and purpose was an ungrounded electric street railway system of traction.

This, in the language of the day (1889), meant a metallic system of return feeders, or an insulated circuit, and not the tracks as the metallic return circuit.

On October 14, 1889, there was not an engineer who would say that this proposed electric street railway construction meant a bonded rail-return circuit, or a grounded system of traction. The thought conveyed through the whole latter part of Section 4 of the October 14, 1889, electrification ordinances, is that of feeders. No mention whatsoever is made of tracks in any sense of the word.

Little thought was given, in the early days, as to the railbonding. Great stress was laid upon the electrical efficiency of earth-plates, and the artificial grounding of the tramrails themselves.

The following article by Mr. George K. Wheeler sets this matter out very clearly:

RETURN CIRCUIT FOR ELECTRIC STREET RAILWAY SYSTEMS

By George K. Wheeler

(The Street Railway Journal, January, 1892, Pages 43 and 44)

The above subject is one which has not received the careful attention it should have from electrical engineers and contractors or railway companies who have in operation or are about to install an electric railway system. It is the purpose of this paper to bring to the notice of such the importance that this part of the installation bears to the operation of any road commercially, satisfactorily and economically. The return circuit may be constructed so that the coal consumption will be largely in excess of that required to operate the road, and the writer regrets to say that a large number of roads are now operating with powerhouse expenses frightfully in excess of what they should be, on account of unbalanced circuits.

The following are the different methods that have been and are now in use, with mention of their advantages and disadvantages: The first method, the oldest, is that of bonding the rails with a No. 4 bare, soft copper wire about thirty-six inches in length, having soldered on each end a copper rivet three-eighths of an inch in diameter. The manner of connecting is to drill a three-eighths inch hole in the rail about eighteen inches from the end, pass the rivet through the hole from the inside of the rail and head it down securely: in addition to this, the bond wires are connected together about every 500 feet with a copper wire of same size as the bond wire, and all connections are carefully soldered.

The objections to this method is the great liability of poor connections, owing to the large number of soldered joints necessary to secure the rivets to the bond wires, and the liability of bond wires of this size breaking by reason of poor joints in track and by teams running on track where paving is not used, and the vibration of track causing the wire to break away from the rivet. Further, the carrying capacity in amperes of this circuit is only sufficient for small lines operating a limited number of cars.

The second method of construction only differs from the first by the use of iron instead of copper wire. This method has only one advantage over the others; that is, its low cost to install. It is, in the writer's opinion, the poorest kind of a return, and after it has been laid for a few months is but little better than the track itself, without bond wires. It is well known that the life of a No. 4 galvanized iron wire when suspended in the air, is about seven years, and its life when underground must be considerably less than this, on account of that great liability of corrosion. Bond wires of copper are used to obtain high conductivity at the joints of the rail, which can not be obtained by means of ordinary plates and bolts on account of the rust which will accumulate at these points; therefore it seems useless to construct the return circuit with iron wire, which has a conductivity considerably less than that of copper. The efficiency of this return is considerably reduced by reason of the rusting away of the wires where they are connected to the rails. Railway companies intending to equip electrically will do well to shun the wire return if low cost of operation and maintenance is desired.

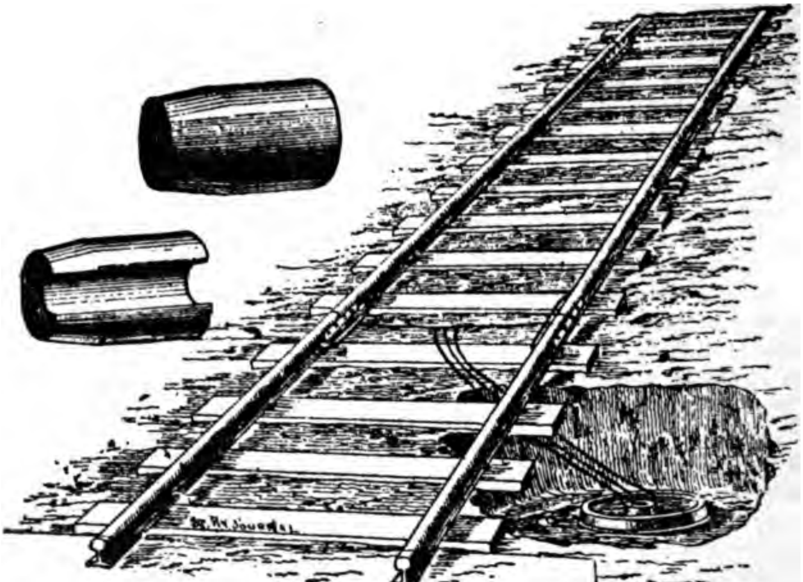
The third method, one which has been generally used and has given good results in a number of cases, is to construct the return circuit in the same manner as in the first method, but in addition to this, use a No. 0 soft drawn bare copper supplementary wire which is laid between the rails in the centre or on the side, as may be desired, and connect each of the bond wires to this wire, soldering all connections. But the same objections apply to this as in the first method, with the exception that it gives a much better return on account of the addition of the No. 0 wire. On some roads of great length where a large number of cars are used, it has been found necessary to run out track feeders in addition to the supplementary wire since the conducting capacity of the rails has not been and could not be fully utilized when No. 4 bond wires were used. Railway companies have often objected to using the supplementary wire on account of the increased cost of track construction, which is about $300 per mile, and have preferred to put that amount of money into overhead feeder lines, so that in a great many cases this has been done, incurring a needless expenditure of money, though without benefiting the system one particle.

The writer has given considerable attention and study to this subject and has made a number of experiments on all forms of return circuits during the past few years, for the purpose of obtaining the most efficient method and one that could be more economically constructed than the third method, where the No. 0 supplementary wire is used, and for the past year has recommended the following form of construction, which may properly be called:

THE IDEAL RETURN CIRCUIT

This circuit is constructed in the following manner:

Drill in the rails, about eighteen inches from each end, a hole nine-sixteenths of an inch in diameter with a twist drill, and connect to each rail a No. 0 soft drawn, bare copper bond wire by means of a channel pin of either pattern, illustrated at the right in the accompanying engraving. Placing the bond wire in the hole from the inside of the track and driving the channel pin in from the outside, secures it firmly to the rail without the use of solder; this is a very decided advantage gained over other methods of bonding, as there is no possible chance of connections being corroded, as there is when solder is used. The cost of labor is also largely reduced as the connection can be made in a very short space of time. In addition to this, the rails are cross-connected every 300 feet, connection being made to the bond wires at these points by means of a copper wire, the same size as the bond wires. This method gives a large carrying capacity, the safe carrying capacity in copper being 260 amperes, in addition to the amount that must necessarily be



carried by the rails. The cost of this, including all materials and labor, is about $300.00 per mile of single track, and as compared with the third method where supplementary No. 0 wire is used and which costs $550.00 per mile of single track, a saving is made of $250.00 per mile, and a much better return is obtained with less liability of breaking of bond wires and corrosion through poor soldering.

In addition to this, on roads over five miles in length, the writer recommends the following:

EARTH RETURN

This is constructed in the following manner and can be used in connection with any form of return circuit: Place an old car wheel deep enough in the soil between the tracks to reach moist earth, connecting the car wheel by means of channel pins to two or three No. 0 copper wires, and connecting the same to the bond wires at that point, and at the power station sink several car wheels in moist earth, the number to be determined by the number of wheels placed in the soil between the tracks, and connect the same by means of wires of sufficient size to the negative side of the generators. This will, in addition to the rails and bond wires, give an earth return which will largely assist in the economical operation of any road, providing the roadbed is not constructed upon ledge rock. This form has been used on several large roads and excellent results have been derived, the motor cars moving very quickly when the current is applied, at all times being a very small amount of current, and greatly reducing the coal consumption at the power station.

On roads where track feeders are required, it is advisable also to install supplementary wires placed in the center of track and connected to each bond wire. This is more economical than constructing track feeders overhead and there is less liability of short circuiting the system.

RIVER RETURN

Good results have been obtained by the use of river returns in addition to the rail and earth returns, and they should be employed wherever possible. If a river runs adjacent to any point of track and the powerhouse, it would be well, in addition to the rail and earth returns, to sink in the river bed old car wheels or metal plates, copper preferred, of sufficient area, and connect the same to the bond wires of the rails by means of No. 0 copper wires. A similar connection should also be made with plates or wheels at the powerhouse and the same be connected to the negative poles of the generators.

On a number of roads which have been constructed the negative poles of the generators have been connected to the overhead line, making rails positive, and the current has passed from the supplementary wire (if used) and bond wires to rails, from rails to wheels, through wheels to motor, through motor to overhead line and back to the generators at the power station. This is bad practice and will invariably work great injury to any system in a very short time on account of Electrolysis, which occurs by reason of the positive current passing from the copper supplementary or bond wires to the iron rails, causing them to be rapidly eaten away, making poor connections, obliging the generators at the station to work at all times under a heavy load and increasing the coal consumption and the liability of injury to the apparatus. The writer has some samples of No. 0 wire which were in soil but a few months, with the positive poles of generators connected to the rails, which are in a very bad condition, being almost entirely eaten away. They were laid in soil that was not affected by any gases or salt water, and the action can only be due to Electrolysis. All systems, in the writer's opinion, should be connected with the positive pole of the generator to the overhead line, and he believes that this is today the standard practice and conformed to by all engineers and contractors.

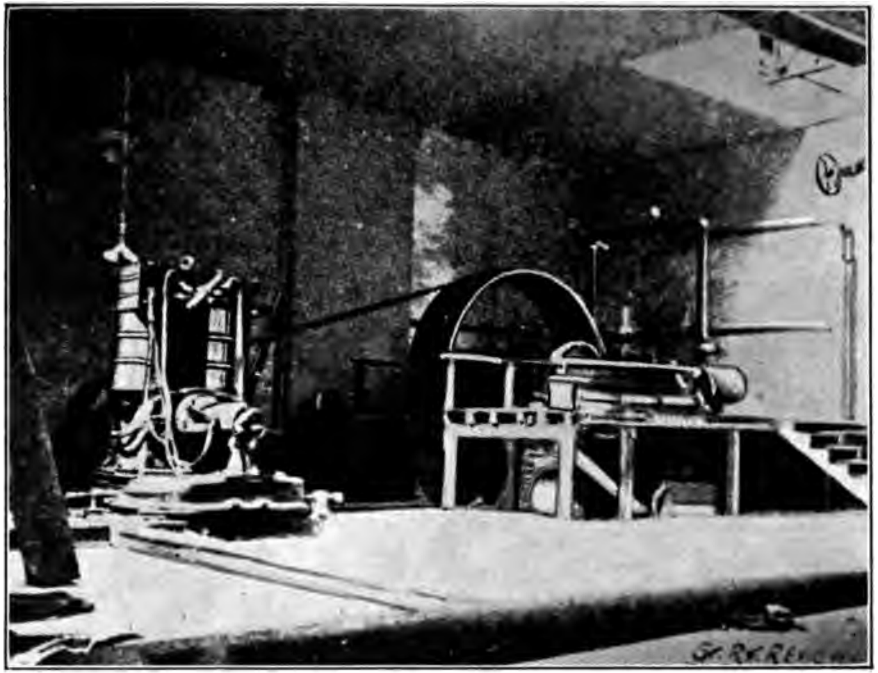
There is one thing more that is equally important as the installation of the return circuit, and that is, the attention that bond wires should receive after a road has been put into operation. They should be carefully inspected by the trackmen whenever possible, and a broken or defective bond wire can be readily discovered at night, as there will always be a flash at the wheels when the motor car is passing this point. Defective or broken bond wires should always be immediately repaired. There is always a marked decrease in the amount of current used in the operation of an electric railway during rainy weather; this is due to the fact that the moisture assists in making a perfect contact between the wheels and the rails, and also allows the current to pass defective bond wires by way of the earth. A great many of the larger roads use a water tank car, which is arranged to allow a flow of water to run on both rails, this keeping the rails wet at all times. On these roads it has been found that considerably less power is required to operate, and that there is an entire absence of sparking at the wheels.

In conclusion, the writer would certainly advise all railway companies who equip electrically to be sure that they obtain the best possible return circuit, and one that will be ample and sufficient for their needs, and he would suggest to those who are at present operating electrically equipped roads that they increase the return circuits which they are now using by adding the earth return above referred to, and also the river return, whenever possible, and thus establish a marked reduction in expenses of operation and maintenance.

Therefore, the chief object in Mr. Wheeler's report was to use the earth largely, as one side of the grounded electrical circuit of the street railway system. This is evidently what the Milwaukee ordinances sought to avoid. The earth path was the old telegrapher's idea of a return circuit.

In February, 1888, Mr. Frank J. Sprague, noted electrical expert and promoter, could not start his 450 volt, direct current, 11-mile, thirty (30) car, single trolley electric street railway system, until he had made numerous metallic connections between the rails and the water piping system of the City of Richmond, Virginia.

In all of the single trolley litigation brought by the telephone companies (who were using the single trolley themselves, in principle) in Albany, N. Y., Nashville, Tenn., Chattanooga, Tenn., Knoxville, Tenn., Akron, Ohio, Eau Claire, Wis., Cincinnati, Ohio, and others, from 1888 to 1894, it was openly admitted, upon both sides, that the earth proper was the prime electrical conductor for one side



THE FIRST ELECTRIC STREET RAILWAY POWERHOUSE IN
MILWAUKEE, WISCONSIN, 1889

(Reprinted by E. E. Brownell)

of the electric street railway circuit. It was over this question that much bitter litigation was being forcibly pressed by the various grounded telephone companies throughout the United States.

Every telephone company throughout the United States in 1889, was using the earth as part of their electric circuit. The telephone companies laid prior claim and rights, beginning as far back as 1876, to the exclusive electrical use of the earth. This the grounded electric street railway companies contended was illegal.

Except in Cincinnati, Ohio, the electric street railway companies won each and every suit tried.

Little or no thought was given, in 1889, as to the electrical carrying capacity of a rail-return circuit.

Beginning with the first electric street car in Milwaukee, on April 4, 1890, and continuing until at least 1894, the local electric street railway companies used nothing but a 5/16 of an inch iron bond wire.

(See the 1893 report, made by Mr. O. M. Rau, electrical engineer for the Milwaukee Street Railway Company on rail bonding, as set forth in a 4-page article in this report, pages 99-102.)

There were six No. 0000 supplementary, copper return feeders, in 1893, extending from the negative busbar, and connecting to the tracks at six different centers of return current distribution, with two 500,000 c. m. copper cables connected from the negative busbar to the tracks in front and along the side of the powerhouse.

The powerhouse evidently referred to in Mr. Rau's report, in 1893, is the one at the corner of Oneida and Edison Streets. It is very questionable, as to whether or not the original powerhouse on Wells Street, between 11th and 12th Streets, was running at that time.

Mr. Rau's report is of considerable value on various conditions throughout the City of Milwaukee in 1893, and particularly upon the subject of electrolysis. It proves, beyond the shadow of a doubt, that the electric street railway companies were cognizant of this menacing evil of electrolysis in the early part of 1893, or earlier. Their installation of a rail-to-water-pipe electrolytic mitigating system in 1893 will be treated under the heading of "Electrolytic Mitigation."

Since then, copper rail bonding has taken the place of iron bond wire. A powerhouse was added to the original one on Wells Street, the Oneida Street station. Then a temporary powerhouse was added (about 1892) at Kinnickinnic Avenue and Mitchell Street, followed by various substations, as distributing centers for the electric street railways up to 1919.

The Oneida Street powerhouse was placed in operation about the year 1892, followed by the Commerce Street powerhouse about 1905. These are the only four powerhouses, for electric street railway purposes, that were ever placed in operation in the City of Milwaukee.

There have been six (6) substation sites in the City of Milwaukee. Not including, however, one for the Milwaukee Northern Railway Company and one for the Chicago, North Shore and Milwaukee Railroad Company, which were both placed in operation on October 20, 1907, and October 9, 1908, respectively, as Single Trolley systems.

These six (6) old and present substations are known as Kinnickinnic Ave., Farwell Ave., Clinton Street, North Ave., West Allis and Oakland Ave., districts. The latter four (4) substations are in operation at the present writing, or 1919, with Oneida and Commerce Street powerhouses, making a total of six (6) distributing sources for electric street railways in the City of Milwaukee, Wis., in 1919.

All of these are supplying 600 volt direct current to the positive trolley, as are also the two (2) interurban substations. This makes a total of eight (8) distributing points of electric street railway currents in the City of Milwaukee.

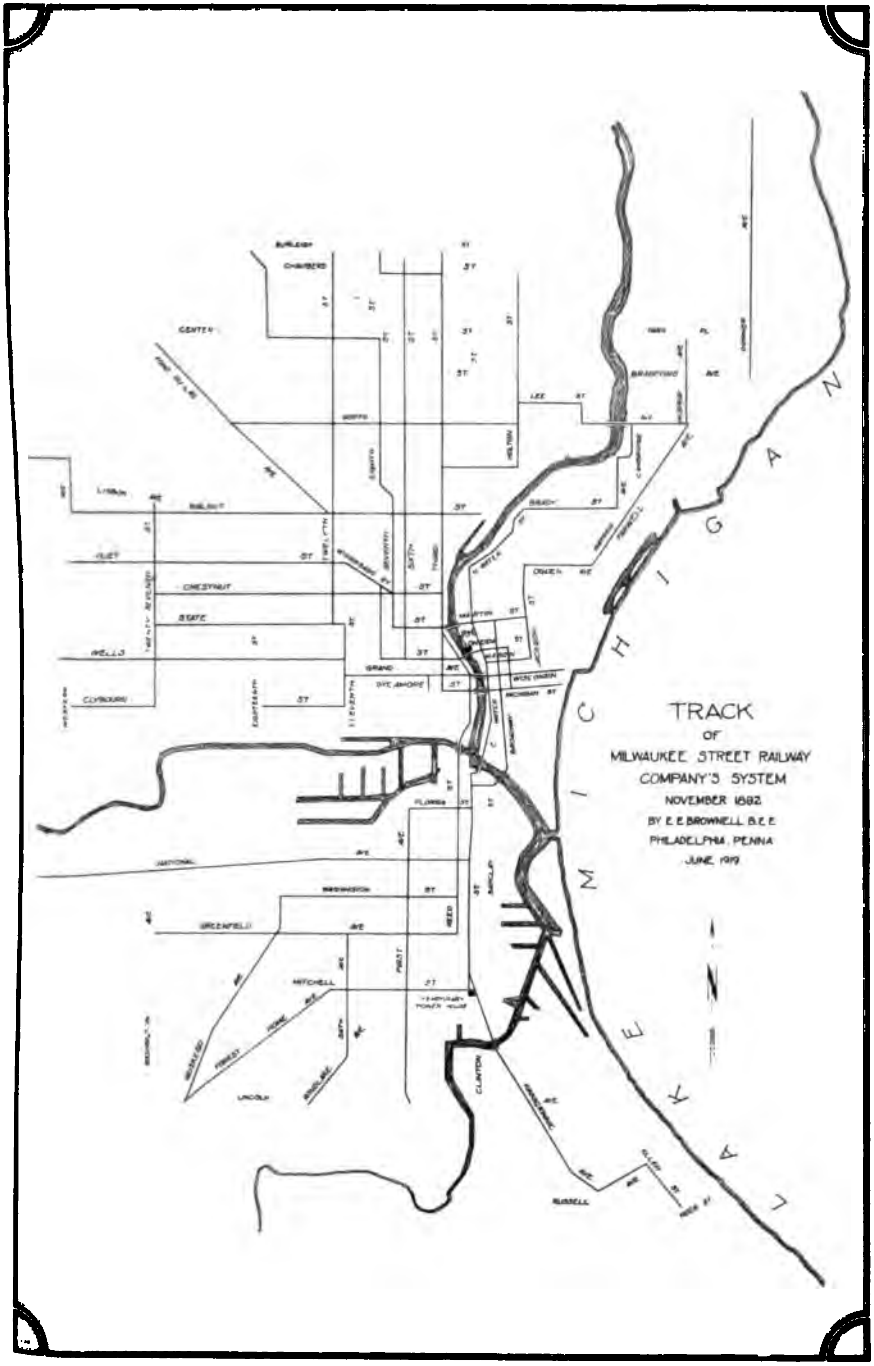
EDISON THREE-WIRE SYSTEM

The Edison three-wire, grounded neutral system has been in use in the City of Milwaukee for about the last 23 years. It was installed by The Milwaukee Electric Railway and Light Company, at the time they assumed control of the electric street railways of Milwaukee, or January 29, 1896.

This direct current, grounded neutral system, can cause considerable electrolytic action upon subsurface metallic structures, when electrically unbalanced.

When the diverted electric currents of a single trolley system, and the diverted currents from an unbalanced three-wire Edison system (110-220 volt) both produce electrolytic corrosion upon subsurface metallic structures in the same vicinity, it is quite impossible to differentiate, as to what proportion each is responsible for without the full co-operation of these utilities.

In any event, the common law does not make it obligatory upon the plaintiff to prove in what proportion each is responsible. It is only requisite to prove that both are participating in a common evil, or electrolytic deterioration on the subsurface metallic structures.



TRACK
OF
MILWAUKEE STREET RAILWAY
COMPANY'S SYSTEM
NOVEMBER 1882
BY E.E. BROWNELL B.E.E.
PHILADELPHIA, PENNA
JUNE 1919

THE NEW YORK
PUBLIC LIBRARY

The writer has seen great damage result, electrolytically, from diverted electrical currents of the Edison three-wire system.

PRESENT ELECTRICAL DISTRIBUTION SYSTEMS IN MILWAUKEE

In any event, the original installation, beginning in 1889, was the Single Trolley system, which will soon have been thirty (30) years in operation. There has been no exception to this mode of operation, on the part of any of the electric street railway lines in the City of Milwaukee from 1889 to 1919.

Judging from the present day outlook, there can not be seen one single indication, that the Single Trolley system (in principle) will ever be changed for urban passenger service.

The cost of labor and materials, in making any constructive or operative improvement over the Single Trolley system, except in minor detail construction and operation, would never warrant the investment of the additional capital necessary on account of the poor financial return.

From a strictly operative viewpoint, the electric street railway industry from 1884 to 1919, has not been as profitable as the general public is led to believe. From a monetary speculative point of view, it has been the means of vast sums passing hands without proper regard to operating conditions, past and present.

Fortunes were lost in the first few years by those who could ill afford to sustain such losses, which is almost inevitably the case.

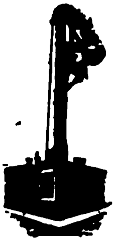
At the present day, 1919, there is no prospect that these electric street railways can get the requisite new money to place their properties in even a proper operative condition. Therefore, their service, as common urban carriers, must suffer as a consequence, and deterioration of the electrical efficiency of their return circuits will invariably result in greater electrolytic destruction to the subsurface metallic structures in the streets of our cities.

Street railways give an indispensable service, and must be maintained reasonably efficient, even if the municipalities are compelled to lend a financial and operative hand in their management, as would appear today inevitable.

Vast sums of money have, no doubt, been made out of the electric street railway systèms of the City of Milwaukee by the holding company (interurban roads not included), with little or no regard to the physical condition of the property or the service rendered.

(Street Railway Review, September, 1893, Page 530)

HISTORY OF RAPID TRANSIT IN MILWAUKEE.



THOSE good old days of Solomon Juneau the favorite and very safe method of intramural transit in Milwaukee was by foot. It is true that this method was not rapid, but it was very safe. No one was seriously injured at grade crossings and a live wire was unknown. Of course a "ground" some times brought grief to the slow but sure method, when Solomon fell down over one of his neighbors pigs on Wisconsin street; but prairie soil is much easier to fall on than is cobble stone pavement, and we may suppose that Solomon arose, kicked the pig, said "sacre" or some other equally expressive swear-word Francaise and proceeded on his way to the corner grocery.

In those Arcadian days, when Juneau and his bold compeers were tenants-at-will of the noble red man, the double tracked cowpath and the double reduction or dirt service for freight and passenger traffic between the few and widely separated neighborhoods.

There were long years of growth before Milwaukee was ready for a street railway line, and many more years of development before electric traction was ready for Milwaukee.

In 1859, so the oldest inhabitant informs us, the subject of street railways was first broached and finally, in the course of a twelvemonth, the River & Lake Shore Railway was built. The first ordinance authorized the River & Lake Shore Railway Company to build and operate in the first, seventh and eighth wards, and on May 30, 1860, the first bobtailed car developed four miles an hour amid a most tremendous ovation from the 30,059 proud souls of Milwaukee. John Lockwood was the organizer of this pioneer company, and his faith in the city has been well realized in the magnificent electric system that greet the American Street Railway Association in 1893. Alexander Easton, of Cincinnati, became the first street railway builder in the Cream City, taking the contract and furnishing the first line of single track on East Water street, or Walker's Point Bridge, as it was then styled, to Division street, now Juneau avenue. Geo. H. Walker, Dr. L. W. Weeks, W. J. Johnson and F. S. Blodgett were the elements of the first company, and Mr. Walker, Milwaukee's first street railway manager.

In 1863 the city council passed an ordinance authorizing the extension of the road on the south side of Walker's Point Bridge to Ferry street, on Ferry to Lake, on Lake to Clinton, on Clinton to Florida, on Florida to Hanover, on Hanover to Elizabeth, on Elizabeth to Sixth, on Sixth to Mitchell, on Mitchell to Forest Home, on Forest Home to the cemetery. The franchise was carried out later.

The Milwaukee City Road succeeded the River & Lake Shore Company. This new institution was organized and promoted by John Plankinton, Frederick Layton, Samuel Marshall, Charles F. Ilsley and Walter S. Johnson, all well known names in the Milwaukee of to-day, and each leaving to the city a greater legacy in business enterprise and development than perhaps any other set of contemporaneous business men. The capital stock was set at twice that of the acquired company, namely, at $100,000. W. S. Johnson became manager of the new corporation, and the routes given by ordinance variously modified to suit the increasing size and importance of the city. Isaac Ellsworth became owner of the Milwaukee City's rights and properties in 1869.

Extensions for the next few years were neither numerous nor rapidly pushed, and not until 1875 did the street railway building attempt to keep pace with the necessities of the case. Between 1875 and 1881, however, a number of lines were built, including the double tracking of the National Avenue Line and the betterment of existing routes. During these years tracks were removed from Ferry, South Water, Florida and Greenbush streets.

(Street Railway Review, September, 1893, Page 531)

In the autumn of 1881. Peter McGeogh took the reins of the Milwaukee Street Railway, as owner and manager. With commendable enterprise and public spirit, Mr. McGeogh began at once the making of the system what it is to-day. He extended the National Avenue Line to National Park, the Walnut Street Line to the city limits and the Third and Eighth Street Lines to the north boundary of the municipality, besides building several other lines outright. Under the improvements the value of the road rapidly appreciated and became known to eastern capitalists. On December 1, 1888, Wall street men became owners, buying the property at $1,500,000. In August, 1890, the Villard syndicate became the owners, uniting it with

THE CREAM CITY LINE,

which was incorporated in 1874, in the leafy month of June, by F. B. Van Valkenburg, Jas. B. Turck, J. B. Hibss, Ed. C. Wall and H. S. Mark. Taking up the streets abandoned by the Milwaukee City Company the Farwell Avenue, Ogden, Jackson and Mason Street Lines were put in operation in 1875. New lines built on East Water street from Juneau avenue across the East Water street bridge to Clinton street, down Kinnickinnick. The Forest Home line was built in 1877, and ten years subsequent all the Cream City Lines were in operation. The first manager of these lines was James B. Turck, who acted with F. B. Van Valkenburg, the first president. Winfield Smith, the prominent Milwaukee lawyer, became president of the Cream City until the absorption by the syndicate.

In April, 1890, the road was sold to a Pittsburg syndicate for $777,000, and again finally transferred to the Villard syndicate in August of the same year in consideration of $890,000.

THE WEST SIDE ROAD,

known as the Becker line, was organized in 1874, by John Tesch, John Plankinton, S. W. Green, S. S. Merrill, and S. S. Harrison, with Mr. Tesch as the first president. Franchises were granted on several west side streets, with subsequent ordinances dated 1876, 1879 and [illegible], with rights to double track and extend original grants. Washington Becker has been at the head of the line since 1875, and for many years T. J. Durnin has been manager. The road is under agreement to sell to the syndicate lines and two-thirds of the purchase money has been transferred. On the third payment the organization will disband.

THE PFISTER LINE

has a history. In common with all things and men who have histories it is interesting, and consists in ups and downs of various gradients. The line has been almost endlessly in litigation, was the first to apply electricity, and is now in the hands of Receiver Melms, waiting for quiet and consolidation. John A. Hinsey paved the way for electricity, by gaining a franchise in 1886 for a street railway line. The fight for the franchise was an exciting one and the franchise called for the cabling of the streets granted. The Rasmussen cable was suggested as the proper method, but upon the failure of that design in New York the idea was abandoned. In 1889, during an eastern trip, Mr. Hinsey first became interested in electric power, which was then just coming into commercial use. This was in 1889, and in 1890, thanks to Mr. Hinsey's strenuous efforts, the franchise was amended to allow the new power. Rapidly following upon the heels of the grant, 1891 saw the operation of the first electric railway in Milwaukee.

Mr. Hinsey owned 40 per cent of the stock and Mr. Hinckley the remainder, and as the latter did not wish to advance more money, the road was given over to Charles Pfister, on a loan of $120,000. November 27, 1892, G. J. Melms was appointed receiver, and June 30 of this year the line was formally bought by Charles Pfister, preparatory to a transfer to the Consolidated.

PART V

STATISTICS BEFORE AND AFTER ELECTRIFICATION OF THE MILWAUKEE STREET RAILWAYS

1. The electrification of the street railways of the City of Mi waukee, Wis., was begun later than possibly in any other city of th United States, especially when considering its size and populatio This, according to the United States census, was 204,468 about th time of the beginning of electrification or in the Fall of 1889.

2. The City of Milwaukee, Wis., had a population of 30,060 the time of the beginning of the first mule street car. It multiplie its population seven (7) times, during the interim of 1859 to 1889, o 30 years. Officially it had about 45,000 population in 1860.

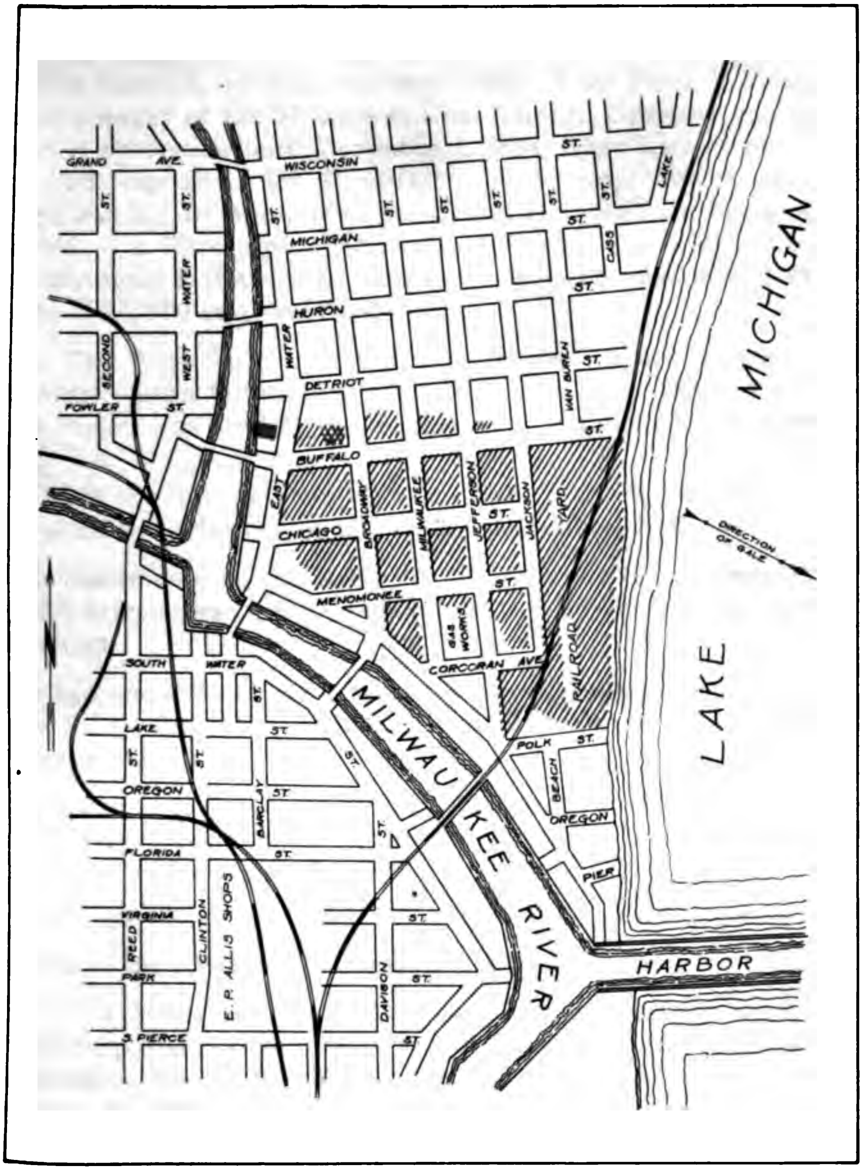
3. In 1880, Milwaukee had 11.41 miles of horse car tracks an in 1890 (electrification date of first car) this had been increased t 52.75 miles of horse car tracks, or 362.31 per cent in ten years.

4. In 1887, Milwaukee had 3 horse car lines, with about 1,18 horses or mules, 208 cars and 2 locomotives. There was carried a annual total of 16,744,000 people.

5. Ending July 1, 1890, three (3) months after the introductio of the first electric street car in Milwaukee, followed by the Crea City Railroad Company's first car about April 30, 1890, there wa the following data on horse cars and the few electric cars that the had at that time.

Total cars, horse and electric, 248. Employes, a total of 61 They carried annually (ending July 1, 1890) 14,512,156 passenger The total cost of the whole street railway systems was given a $4,208,956.24 up to and ending July 1, 1890.

6. Alexander Easton, a contractor of Cincinnati, Ohio, built th original system, about 2 miles of horse car line, in 1859-60. The subscribed capital stock was $50,000. George H. Walker was its firs manager. This road, known as the "River and Lake Shore Road," was succeeded, in 1865, by the "Milwaukee City Railway Company," with a capital stock of $100,000. In 1869, Isaac Ellsworth owned al



October 28, 1892

The great Milwaukee fire, which destroyed 400 buildings and caused a loss of over $4,000,000.

The solid *red* block is where the fire started.

What might happen to Milwaukee again, with an impaired, or electrolyzed, water piping system.

(E. E. B.)

the street railways, holding same until 1881. Then Peter McGoegh became manager of the Milwaukee City Railway Company and remained in possession until December 1, 1888, when he sold out to New York capitalists for $1,500,000. In August, 1890, it again changed hands. In April, 1890, the Cream City Railroad Company was sold to a Pittsburgh syndicate for $777,000 and bought back again on August 1, 1890, by the Villard people for the sum of $850,000, a profit of $73,000 in a few days.

7. The West Side Street Railroad Company, which started the first electric car in Milwaukee, was organized in June, 1874. Washington Becker was head of this road from 1875 to about December, 1890.

The West Side Railroad Company had 19 miles, out of its 21 miles of railway, electrically equipped in December, 1890.

Its powerhouse on the north side of Wells Street, between 11th and 12th Streets, was a brick building 60 feet by 120 feet and three stories high.

It had one 250 and one 350 horsepower Reynolds Corliss steam engine, fed by four (4) one hundred (100) horsepower upright Reynold steam boilers.

There were four (4) one hundred (100) kilowatt Edison generators. A continuous copper return was connected to the track, in front of the powerhouse only.

There were 34 motor cars and 35 trail cars in use in the year 1890.

Most of the rails were of a 63-pound Johnson type.

8. The Milwaukee Cable Railway Company was authorized to use electric power, by the City of Milwaukee, on September 11, 1889, by Ordinance No. 92, which amended the original ordinance passed December 19, 1887. (See the last four lines of section 3, page 8 of the Compilation Section of this report, as to the Double Trolley requirement.)

Mr. Hinsey owned 40% and Mr. Hinckley 60% of the stock, which they sold to Mr. Charles F. Pfister for a loan of $120,000.

THE PFISTER-HINCKLEY CASE AGAIN

(Street Railway Review, July 1, 1892, Page 404)

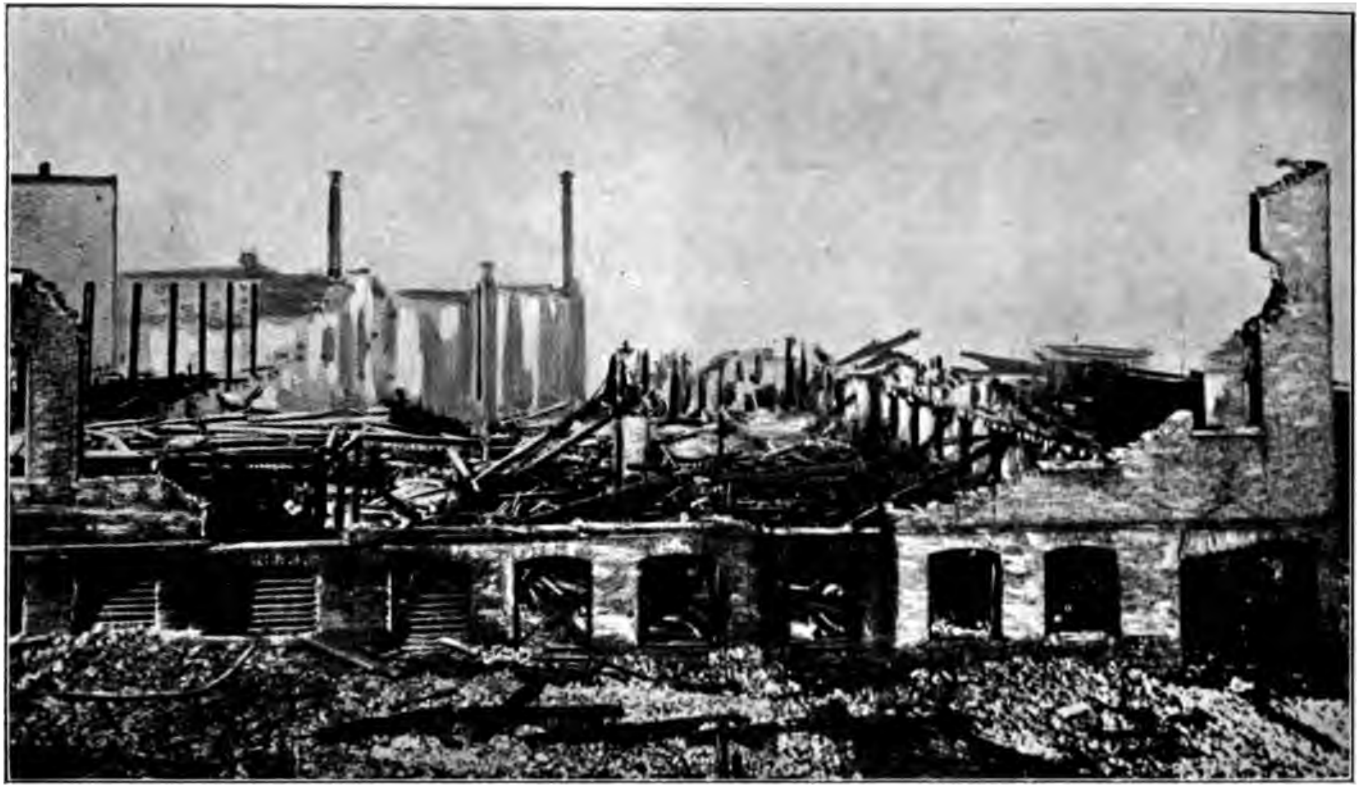
The much litigated Milwaukee Electric Railway has received another turn in the courts, the conditions of affairs through excessive litigation having reached a pass where even the proverbial Philadelphia lawyer can scarcely keep tab on things. The latest is the first decision in the famous litigation of Chas. F. Pfister and August Vogel against the Milwaukee Electric Railroad Company, Francis E. Hinckley and others, was given by Judge Johnson, and resulted in a black eye for the plaintiffs. The decision came on a motion for judgment of foreclosure on the pleadings. It seems that the company, through its agents, hypothecated $250,000 in bonds to the plaintiffs to secure a loan of $125,000. The statutes of the state provide that stock shall not be sold for less than par nor bonds for less than 75 cents on the dollar. The plaintiffs argued that the hypothecation did not amount to a sale but on this point Judge Johnson took exception, and decided that the bonds, if not issued by the company had no valid existence; and if sold contrary to the law they were invalid. In giving his decision the judge referred to a decision of the supreme court in which it was held that the bonds were not only invalid, but that the money paid for them could not be recovered. This was done to show that the court had even gone beyond the letter to sustain the spirit of the statute. The motion for judgment on the pleadings was denied, and carried with it the motion of Manschott to intervene as a party defendant to protect his rights as a bondholder, under the decision, his rights having no standing in the proceedings thus far developed.

The case is a novel one, and stands alone in some of its bearing in legal jurisprudence.

9. On December 27, 1890, and between that date and January 30, 1894, all street car lines were consolidated into The Milwaukee Street Railway Company, thus making an electric street railway system of about one hundred (100) total miles of track in the City of Milwaukee, known as the Villard system. It had a total of about two hundred (200) cars, of the Laclede, American, St. Louis, Brownell, Gilbert, Brill, Jones, Northern, Stevenson, Ellis and Lamokin types.

10. In 1892, the powerhouse located at Oneida and River Streets was completed. It was a 100 by 103 foot concrete and brick building, 95 feet high. The triple expansion engines installed were designed by J. C. Henderson, New York, N. Y., and built by J. Morton Poole & Co., of Wilmington, Delaware.

11. The original installation of dynamos was five (5) No. 60 Edison direct current dynamos. These were soon after changed to 12 multipolar dynamos of two hundred (200) kilowatt capacity each, or a total kilowatt capacity of 2400. This was for the electric street railway load only in 1892.



BURNING OF THE OLD KINNICKINNIC BARNS, DECEMBER 28, 1892

12. The River Street powerhouse, at that time, had nine (9) Galaway steam boilers. Later, 8 more were added. Each boiler was of two hundred (200) horsepower, which made the original total 1800 h. p., with 160 pounds of steam pressure. The steam plant was a condensing one, from the beginning.

13. In 1892, the Villard system was under the direct management of George W. Hummell, who had his office on West Water Street, the main office being at Mason and Milwaukee Streets.

On December 28, 1892, following the big Milwaukee fire on October 28, 1892 (exactly 60 days apart), the 204 by 270 foot building, two stories high, at Kinnickinnic Avenue and Mitchell Street, was burned. There was a loss of $135,000 in buildings, tools, machinery, etc.

14. A temporary steam generating plant was in operation near Kinnickinnic Avenue and Mitchell Street from 1892 until a year or two later. This plant was of a thousand (1,000) horsepower capacity.

REORGANIZATION OF THE MILWAUKEE (WIS.) STREET RAILWAY COMPANY

(The Street Railway Journal, July, 1895, Page 485)

Messrs. Frederick Olcott, Arnold Marcus, William N. Cromwell and Charles W. Wetmore were, on June 6, appointed a committee to reorganize the Milwaukee Street Railway Company under an agreement and plan already assented to by holders of a large majority of all the securities of the company. The reorganization plan provides that a new company shall be organized which shall issue the following securities:

$3,500,000 of common stock.

$3,500,000 of 5% preferred stock.

$7,000,000 of first consolidated mortgage 5% bonds. The mortgage is to cover all properties of the Milwaukee Street Railway Company, except some real estate not used by the company, the proceeds of which, after sale, is to be used for betterments and improvements.

The new company will be authorized to increase its preferred stock and its mortgage bonds $1,000,000 each, the proceeds to be used for additions and extensions of the plant.

Of the $7,000,000 first consolidated mortgage bonds, $1,500,000 is to remain in the hands of a trustee, against a like amount of existing underlying first mortgage bonds, and the remaining $5,500,000 are to be divided prorata among the now outstanding first consolidated mortgage bonds, under which division these mortgage bonds will receive 61.756 per cent in bonds, and, will receive in addition 38.244 per cent of their par value in preferred stock of the new company. The outstanding unfunded coupons of this mortgage, to the amount of about $40,000.00 will be exchanged as par for preferred stock. The coupons due on outstanding first consolidated mortgage bonds will receive 61.756 per cent in cash.

Of the $3,500,000 common stock, $2,550,000 will be given in exchange for $1,275,000 second consolidated mortgage bonds of the old company. The remaining $950,000 of the common stock to be issued will be divided pro rata between the stockholders of the present company, who thereby receive 20.2 per cent of the par value of the present holdings in new stock.

The assent to this plan of security holders largely in excess of a majority of each class has been obtained. The Central Trust Company, of New York, N. Y., is the depositor of securities under the agreement and will issue its certificates of deposit therefor.

15. On December 23, 1895, the Central Trust Company of New York, foreclosed a mortgage upon the Milwaukee Street Railway Company and after various procedures, the property was acquired by The Milwaukee Electric Railway and Light Company, on or about January 31, 1896. The Milwaukee Electric Railway and Light Company was chartered on January 29, 1896, under the laws of the State of Wisconsin.

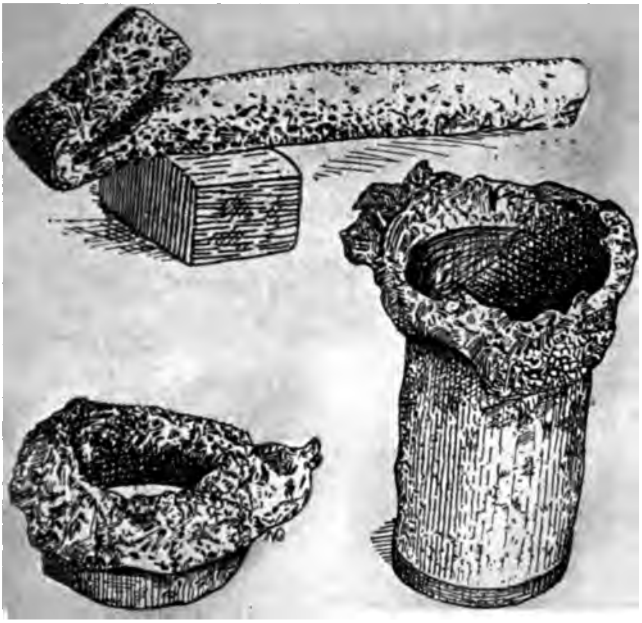
THE MILWAUKEE ELECTRIC RAILWAY AND LIGHT COMPANY OF 1917

Up to January 1, 1918, The Milwaukee Electric Railway and Light Company, in the railway department for 1917, report owning 168.28 miles and leasing 27.51 miles of track. Girder and T rails. This makes a total trackage of 195.79 miles, of which only 180.38 miles are operated.

The company owned 574 cars and operated (average) 519 of them.

They carried 107,528,091 passengers in the year of 1916 with a gross income for the year of 1917 of $7,968,192.00, on a physical property and plant, which they claimed was worth the sum of $39,799,735.00 in 1917.

The North American Company of 30 Broad Street, New York, N. Y., is the parent company of The Milwaukee Electric Railway and Light Company.



Electrolyzed Lead Water Service Pipe taken up on
Wells Street, between 11th and 12th Streets,
Milwaukee, Wisconsin, April 29, 1893

(Compiler's Comment of June, 1919)

The first known case of electrolysis in the City of Milwaukee, Wis., was found at the above locality in April 1891.

—E. E. B.

PART VI

ELECTROLYTIC CONDITIONS IN CITY OF MILWAUKEE, WISCONSIN

1. Before the introduction of the Single Trolley System in the City of Milwaukee, the grounded telegraph and telephone systems discharged so little direct current into the earth, that the electrolytic deterioration resulting therefrom was negligible.

2. With the starting of the first single trolley electric street car on April 4, 1890, came resultant electrolytic action upon the gas, water, lead-sheath covered cables and other sub-surface metallic structures in the city of Milwaukee. This has continued ever since, or a little less than 30 years.

3. The property owners along Wells Street, between 10th and 12th Streets, whose lead water service pipes were found to be deteriorating and leaking, as early as in the Spring of 1891, were more or less puzzled.

4. The direct cause for this deterioration was soon found to be electrolytic action from the diverted electric street railway currents of the West Side Railroad Company, whose powerhouse was located on Wells Street, between 11th and 12th Streets.

5. The lead water service pipes continued to be electrolyzed in this district, along Wells Street. On April 29, 1893, the 6-inch c. i. water main broke and flooded Wells Street.

6. It was the duty of Mr. George H. Benzenberg, then the City Engineer, to inspect all water breaks. After a careful survey of all local conditions, Mr. Benzenberg pronounced this cast-iron water break due to electrolysis corrosion. (See photograph in this report showing the 6-inch electrolyzed cast-iron water main).

7. This report of Mr. Benzenberg's was one of the very first official statements showing electrolytic action upon cast-iron water mains, that was ever made up to that time, April 29, 1893.

8. Following this trouble on the Wells Street water main, Mr. Benzenberg consented to connecting a copper wire between the water main and the rails in front of the powerhouse of the West Side Rail-

road Company. The request was made by the said Railroad Con pany, and the installation paid for by them. This was during tl Spring of 1893.

9. In the Summer and Fall of 1893, 50 rail-to-pipe conne tions were made by the railroad company, but without the full know edge or consent of Mr. Benzenberg. It is said that many of the: connections were made where water pipes were highly electricall negative to the rails.

10. Now comes one of the important revelations of this r port, namely:

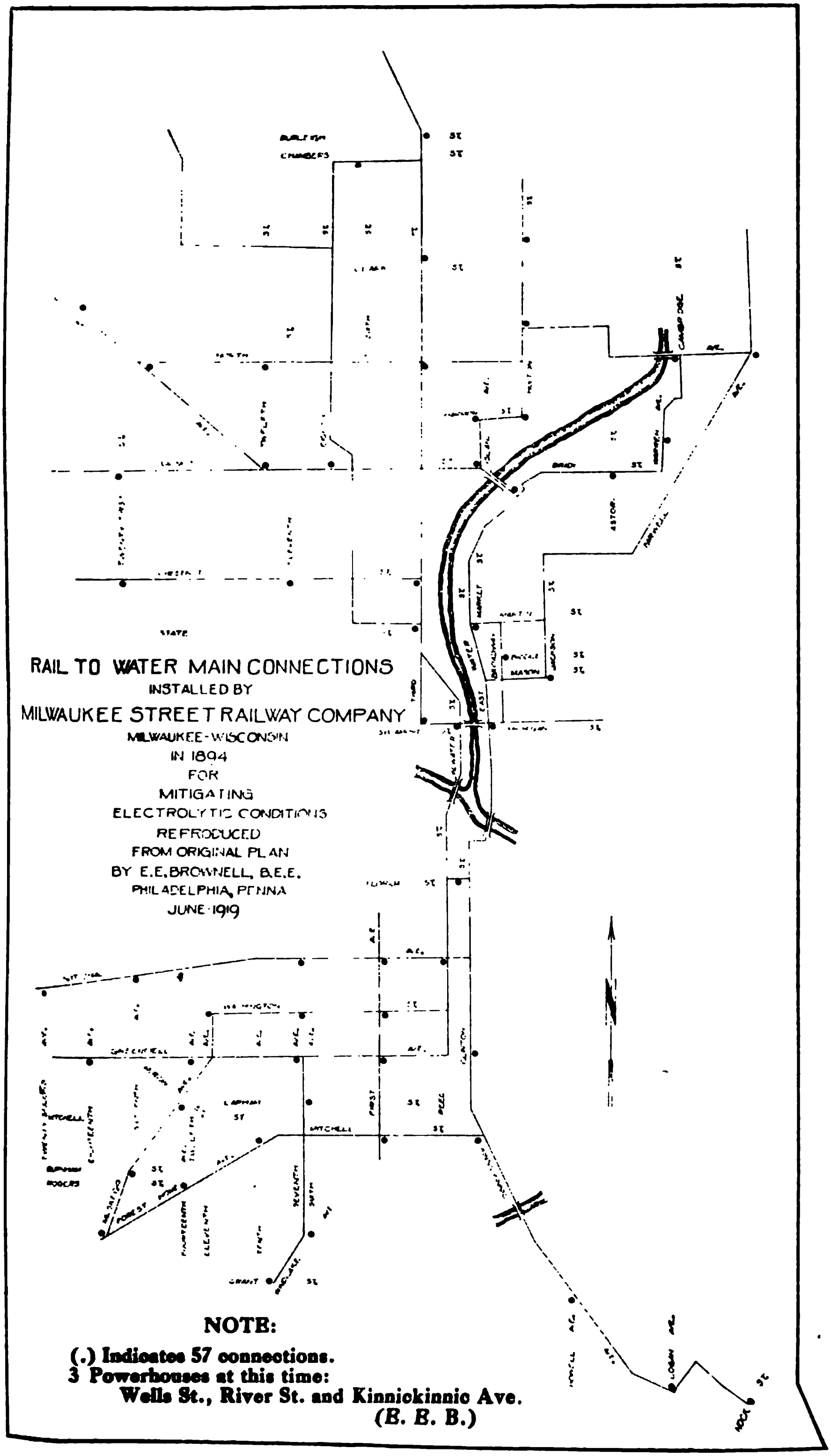
THE MILWAUKEE STREET RAILWAY COMPANIES

(Street Railway Review, December, 1893, Pages 544-545)

SOME FEATURES

"that are commended to the investigation of visitors at the conver tion are the methods of ground return, which are by rail and by wat pipe, the tension being equalized by cross wire connections of the: two media, at intervals where they are in proximity. Tests sho that electrolysis is avoided, and that the return is much better."

In 1893, Mr. O. M. Rau, electrical engineer, Milwaukee Stre Railway Company, read an exhaustive report before the Wisconsi Electric Club, as to what measures his company was taking to ove come the serious effects of electrolytic action upon the water work piping system of the City of Milwaukee. The following report is s important, that it is herewith reprinted in full, but no exact dat could be obtained as to when it was read. It was, however, in tł year of 1893.



RAIL TO WATER MAIN CONNECTIONS
INSTALLED BY
MILWAUKEE STREET RAILWAY COMPANY
MILWAUKEE-WISCONSIN
IN 1894
FOR
MITIGATING
ELECTROLYTIC CONDITIONS
REPRODUCED
FROM ORIGINAL PLAN
BY E.E.BROWNELL, B.E.E.
PHILADELPHIA, PENNA
JUNE 1919

NOTE:

(.) Indicates 57 connections.
3 Powerhouses at this time:
Wells St., River St. and Kinnickinnic Ave.
(E. B. B.)

REPORT OF O. M. RAU

(Street Railway Review, December, 1893, Pages 767-8-9)

THE RETURN CIRCUIT OF AN ELECTRIC STREET RAILWAY, IN MILWAUKEE, WIS.

A Paper Read Before the Wisconsin Electric Club, by O. M. Rau, Electrical Engineer, Milwaukee Street Railway Company.

The subject of a return circuit for an electric railway system has been the cause of much discussion, both in journals and lectures. The prevailing opinion formed from these discussions, is that the return circuit is insufficient, and that innumerable troubles can be avoided by increasing the return circuit. Hence, the question arises, will this ever be made large enough? The main object of a ground return, is to have as small a loss as possible, so as to avoid the troubles which are attributed to this part of a railway system. An excessive drop of potential in the return circuit, not only gives poor results in the operation of cars, but greatly facilitates the electrolytic action on surrounding metallic bodies, which has given much anxiety to both electricians and city engineers. The ground has been relied on as a conductor, but to what extent or percentage this medium acted as such, has until lately not been considered; and even at this late date, it is proposed to use the earth through the medium of ground plates, placed at regular intervals along the track, and sunk into the earth to a depth where permanent dampness can be found. To demonstrate the usefulness of these plates, an incident connected with the railway system in this city will afford a good example. The bridge cable became parted by accident, causing the current to the bridge to be cut off. To avoid delay it was proposed to sink a ground connection at the edge of the river, and another at the bridge, and derive a current in this way to operate the cars and bridge motor. Car wheels, to which were attached a 0000 copper wire, were sunk to the bottom of the river, at a distance of 150 feet from each other, but it was found that a current not exceeding 20 amperes was all that could be obtained through the circuit. Hence, that amount being barely sufficient to operate the draw-bridge motor, the project had to be abandoned and a temporary metallic conductor laid until the cable was repaired. Considering these conditions, where every possible advantage for a ground connection was at hand, it is very evident that the ground plates add very little to the return circuit of a street railway system. To increase the return circuit, so that the loss would be very small, would considerably increase the cost of construction, and it is here where the great trouble lies. It must be admitted that the cost of a good return is certainly very great in the construction of a railway plant, but it is, however, only a simple matter to calculate how long the plant will be in operation before the ground return circuit will pay for itself in the saving it has made. This fact is often lost sight of, while it should be the primary consideration for constructing engineers.

In some of the earliest electric roads the ground was omitted entirely as a conducting medium, and a return circuit was calculated for a certain drop and the conductor laid accordingly.

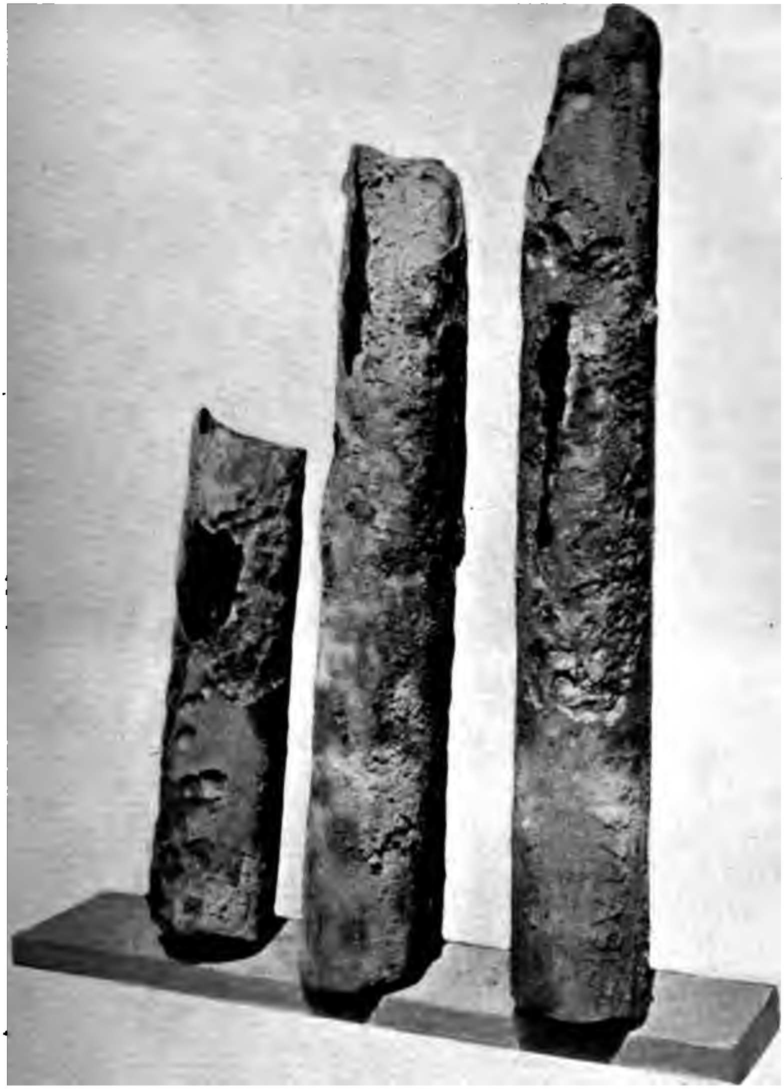
In the electrical equipment of one of those roads, each length of track was connected to this conductor (which was of copper) and the bonding, which was not very thoroughly carried out, was only relied on as a substitute. This, although a very expensive construction, proves that the ground return was considered as important, by early electricians, as any other parts of the system. It is only through the saving in the cost of construction that this part of the system has brought itself so conspicuously before the public. With the supply feeder it is a simple question of how much drop to allow for, and calculate the size of the conductors accordingly, and the amount allowable for this drop is readily ascertained by comparing the amount to be used in this part of the system, and the amount the system, while operating, can afford to loose, which is directly dependent on the cost of generating power, but we have a basis upon which accurate figures can be made and we can determine what is going on in this part of the system. In the ground return it is an entirely approximate figure, and in but few roads is it taken into consideration at all; it being simply stated that there is no drop in the return circuit. Since it is a very complicated and difficult matter to arrive at accurately, either by calculation or test, this statement is generally accepted. The return circuit being in the ground escapes the usual inspection which the other parts of the system are subjected to, and any defects which otherwise would be noticed are left to take care of themselves, except when complaints are received from drivers of vehicles whose horses have received shocks; a broken bond or a defect in the return circuit would not be discovered and would receive no attention. During the winter the defective spots on the return circuit are quite easily located, when a faulty rail bond will keep the snow and ice from forming around the joint and a damp spot will there be found while the earth will be frozen around it. A system of bonding where the bond will have the same conducting area as the rail is sufficient with the present heavy rail construction. In a system, however, where a number of independent lines are constructed radiating from one or two main lines this is not advisable, even if the rail bonds and rails have capacity enough to carry the current with a low percentage of loss. Tracks have to be torn up and repaired and in some cases left out for a length of time. To have the return entirely dependent on them would cause inconvenience to the repair work as well as an occasional stop on the system. This of course could be avoided if care is taken and the tracks cross-bonded with the up and down tracks, as both are rarely disturbed at one time.

If, however, repairing is done near the power house, where the ground connection is made with the station generators, it is a question whether the carrying capacity of the undisturbed rails is large enough. When such conditions arise, the advantage of return feeders laid to different distributing centers can hardly be discarded. A system thus constructed will not be subject to the criticism of the daily papers, by their reports of runaways caused by a charged rail, and it would assuredly be a great friend to the horses.

This has been very forcibly brought to my notice in this city, where we have both systems of ground return. When out driving the horse will cross the return feeder system track very gently, but when he comes to the tracks dependent alone on the bonding for return, he will try to avoid stepping on them, or race across at a Maud S. pace.

Whether the horse is an expert on bonding I do not know, but it is evident that he does not desire to be the medium for increasing the return. Where a return feeder is used, it is almost impossible to shock a horse while crossing the tracks, as they are fed two ways. A broken bond will not open the circuit.

The size or amount of these return feeders is an approximate calculation at best, but by using good judgment for their distributing centers, and considering the number of cars liable to be in the vicinity of these centers at one time, a fairly accurate size can be determined on. By allowing a drop of 25 per cent in these feeders (not including the rail), a very efficient return circuit is obtained if the track is carefully bonded. Although, as I have already shown, the return feeder will be very expensive as an outlay at first, yet I have no hesitation in saying that it will more than pay for itself in the saving in the coal pile, besides giving satisfactory results in the operation of the road. The deterioration of the ground feeder, or supplementary wire, as it is sometimes called, is brought in as an argument against them, but if properly laid, there is no reason for any anxiety from this cause. A very durable plan for laying these feeders is to

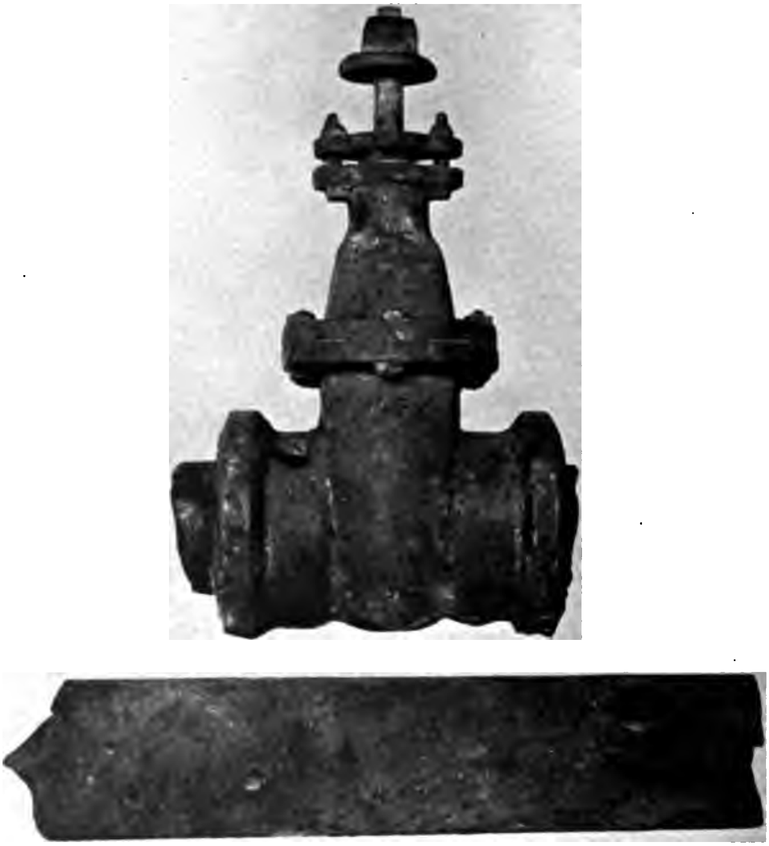


An electrolyzed 6-inch cast-iron water main, Wells Street between 11th and 12th Streets
Milwaukee, Wisconsin

Burst April 29, 1893

(First electrolyzed cast-iron water main in Milwaukee)

Laid May 21, 1873



An electrolyzed 4-inch cast-iron fire hydrant branch, 202-204 West Water Street, Milwaukee, Wisconsin. Burst December 2, 1898.

Laid August 3, 1872.

lay the bare copper wire in a piece of grooved lumber, the groove being considerably larger than the wire. The end of the lumber should be cut at a sharp angle, so that the joints will overlap and allow for a nail to be driven in them to hold them firmly. The groove is then filled with a mixture of tar and pitch, at a ratio of eight barrels of pitch to one of tar. This mixture is pliable, and expands and contracts enough with the changes of the atmosphere and prevents dampness from the copper wire. A wood cover is nailed over the top of the groove after being filled. The trench in which the return feeder is laid is about one foot deep, and is run near the inside rail. The distribution of the return current is also much more complete by a system of this kind.

The track near the power house is as little overloaded as that a mile away, as the current is taken from the track by the feeders and returned through them to the station. The street railway in this city has the advantage of an excellent return feeder, that is giving very satisfactory results, notwithstanding the difficulties encountered in the opening of streets and constructing of sewers through the lines of the railway, besides having numerous draw-bridges and the power house located some distance from any of its lines.

The tracks are mostly heavy girder rails, which are securely bonded with bonds of $\frac{5}{16}$ inch iron wire. This plan of bonding was specified in the construction contract and carried out accordingly. The bond used in this construction is perhaps worthy of a little explanation. It consists of a piece of iron wire, bent at right angles at each end. The length of the bond head is sufficient to allow for a washer, with a groove on one side to fit the main part of the bond, and to go through the web of the rail.* This washer lies against the rail, forming a shoulder, so that when the bond is riveted to the rail, it makes a solid joint. Although the bond consists of three pieces, electrically it is only one. These bonds are at every fourth joint cross-bonded to the four rails of a double track road. The cross-connections consists of $\frac{3}{8}$ inch iron cable. This system of bonding is carried out throughout the entire system.

The tracks nearest to the front of the station are connected to the ground bus bar in the power house with a 500,000 circular mil cable, and those nearest the rear of the station with a cable of the same area, which crosses the river. Besides these there are six return feeders of 0000 copper wire also connected to this bus bar. These feeders extend to six different centers of distribution, where they are connected at intervals of 200 feet to the track which they are intended to feed. By this means there are eight independent returns to the station. The most important part of the ground return system is the manner of making connections to water mains, and it is to this important feature of this system that this paper was first intended.

Electrolysis has caused a great deal of trouble between city engineers and electric railways on account of the injury done to city water mains, and as city engineers have placed the responsibility on the railway company, it is apparent that something should be done to avoid this action. Here comes the question; can enough ground return be laid as to avoid this action? I have a few photographs of pipes taken out from the city water mains. Number 1 was taken from a point in the street about 200 feet from the power house. The railway near which this pipe was, had been in operation four years before the pipe was taken out. The rails were bonded Number 4 copper wire, and a Number 0 copper supplementary wire was laid between the rails, and not being protected in any way it became so badly corroded as to render it almost useless. Number 2 shows where a connection was made to the water main with a piece of copper wire. Between this wire and the pipe a wedge was driven to tighten the wire to the pipe, then on raising the wire a distance from the pipe, on one side the action took place between the wire and the pipe, thus eating it away as shown.

It is apparent that as long as there is a conducting medium in close proximity to the track, which is of a comparative resistance to that of the track or return circuit, a portion of the current in the track will flow into this conductor unless it is insulated from the return circuit; and as this is impossible, the portion of current carried by this conductor is in proportion as the combined resistance of the connecting medium and conductor is to the return circuit.

Although it is almost impossible to measure these quantities, we can for example take a track having a resistance of 10 ohms and the water pipe which is at an approximate figure of 10 ohms; slip the electrolyte or conducting medium between the track and pipes at 190 ohms and the current carried by the pipe will be as 10 is to 200 or 1-20, and if the current is 100 amperes the pipe will carry 5. The electrolytic action of 5 amperes of current on an iron pipe in favorable soil is considerable and this is not an extreme case. That the resistance from the track to the water pipe in some cases is very low, is undoubtable and as it is not an equal resistance through its entire length is the detrimental point. If there were a leakage from the rail to the pipe on its entire length we would not hear from this trouble for years to come; but as it is accruing in one place more than another it decomposes the iron at that point more rapidly. It is apparent that the place where the current leaves the track to go to the water pipe will show no signs of electrolytic action, but as the pipe has the current it will leave it at some distant point and it is at this point that the pipe is affected. This is generally near the power house or where the least resistance is offered to the passage of the current in the pipe, to the ground bus at the station.

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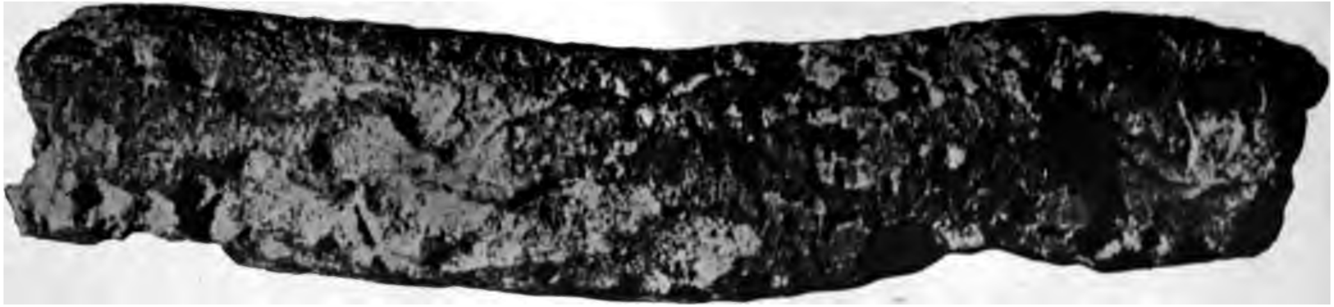
*For full description of this bond, which is the invention of A. Von Hoffman, of Milwaukee, see page 120 of the STREET RAILWAY REVIEW, for July, 1893.

To overcome this it is necessary to insulate the pipe from all possible grounds which are apt to form an approximate low resistance, so as to have a universal leakage from the track to the water pipe, or connect the water pipe to the track so as to have no difference of resistance between them, or the ground bus at the station. By this latter means the current will form no electrolytic action at any one place more than another, nor in fact at any place at all. The current will be conducted to and from the pipe through conductors and not through an electrolyte, thus avoiding all possible decomposition by the current. This plan is at present in vogue on the railway system in this city and it met the approval of the city engineers after much investigation, careful research and consideration. A very careful record is being kept to prove the success of this system. To the forty miles of road there are sixty water main connections made with iron clamps thoroughly cleaned inside and the pipe is filed smoothly where the clamp comes in contact with it. Bolted to the clamp is a lug to which is soldered the connecting cable which runs to the four tracks. The clamp and pipe are thoroughly painted with a water proof paint to prevent corroding. This joint after being laid one year has proven to be as good as when first made. To insure a perfect connection to the ground bus in the station a 500,000 circular mil cable is connected to the large 10-inch water main in front of the station and a similar cable crosses the river and is connected to a 12-inch main on the opposite side of the river.

In experimenting before the water pipe connections were made I found that a wire connected from the water pipe in the station to the ground bus gave quite a spark, and on applying an ammeter it registered from 3 to 6 per cent of the total load of the station on a dry day, and on a wet day as high as 10 per cent. This plan of connecting the water pipe throughout the city with the tracks, and having a good return connection from them to the station bus bar, not only insures the city against any deterioration of the water pipes, but increases the ground return very materially, and in tests made on the railway plant in this city I find that 28 per cent of the total output is returned by the water mains, and this percentage remains constant during damp and dry weather, which proves that there is no leak of the current to the pipe through the improved conductivity of the earth. This increase in the return circuit represents an investment of $8,000.00 on return feeders and increase in the return of 28 per cent, which is a very important factor in the operating expenses of an electric railway and as far as present indications show avoids any further electrolytic action.

11. Most of Mr. Rau's report speaks very clearly for itself, but a few deductions are herewith made. (a) The single trolley electric street railway system was then (1893) known as The Milwaukee Electric Street Railway Company, with its powerhouse at the corner of Oneida and River Streets. It is very doubtful, as to whether or not the powerhouse on the north side of Wells Street, between Eleventh and Twelfth Streets, was in operation at this time. There was, however, a temporary powerhouse, of 1,000 horsepower capacity, at Kinnickinnic Avenue and Mitchell Street, which had been in operation about one (1) year. (b) Mr. Rau admits making 60 of these metallic water-main-to-rail connections, but an old record of 1894 found in the office of the Superintendent of Water Works, City Hall, only showed 57 of these connections. The plan was evidently made



FIRST PHOTOGRAPH OF ELECTROLYZED LEAD WATER SERVICE PIPE IN THE UNITED STATES.
TAKEN IN 1892. FROM SAGINAW, MICHIGAN.

(Reprinted by E. E. Brownell)
(September 1, 1919)

up and filed with the City of Milwaukee after the work had all been done, as it was dated 1894. (See map for location of these 57 connections in this report). (c) Mr. Rau does not say that the City of Milwaukee, through its officials, participated in this plan of electrolytic mitigation, yet he admits it cost The Milwaukee Electric Street Railway Company the sum of $8,000 to do the work. (d) Mr. Rau further admits, that this system of "Pipe Drainage" returns 28% of the current output of the powerhouse, or powerhouses, over the lead-calked, cast-iron water works system of the Milwaukee Water Works. (e) Furthermore, that a 500,000 c. m. copper cable was connected from the negative busbar, in the Oneida Street Station, to the 10-inch c. i. water main in front of this powerhouse.

12. In August 1900, the writer found positive evidence that this 500,000 c. m. copper cable connection to the 10-inch c. i. water main was still attached.

13. On page 10, third paragraph from the top of the page, of a joint report made by Ray Palmer and W. R. Brown, dated September 30, 1911, to H. E. Briggs, Commissioner of Public Works, and Daniel Hoan, City Attorney, will be found a verification of Rau's 1893 report.

14. The 1911 report by Ray Palmer and W. R. Brown was compiled and printed by the writer, for the purpose of making it a part of this report, including various charts, photographs and plates produced by Palmer and Brown.

15. Between the years 1893 and 1900, there is little information to be had, as to whether or not, the Rau electrolytic mitigation system of 1893 was kept up by the succeeding company.

16. The American Water Works Association held its annual convention in Milwaukee, Wis., on September 5-8, 1893. At this meeting a Mr. Milne made a very interesting report on "Electrolysis" and Mr. George H. Benzenberg, city engineer, Milwaukee, discussed the local electrolytic conditions at considerable length.

17. At the 1894 annual convention of the American Water Works Association, held in Minneapolis, Minn., August 21-23, Mr. C. Monjeua read another paper on "Electrolysis" and Mr. G. H. Benzenberg again participated very much in the discussion that followed. (See the Compilation Section of this report for full details.)

Also another paper on "Electrolysis" by A. A. Tucker, of Memphis, Tenn., was read at this same convention, and showed that at the Twelfth Annual Convention, in New York City, in 1892, Mr. Tucker had discussed this matter considerably. (See the Compilation Section of this report for detailed description.)

18. The American Water Works Association formed an "Electrolysis Committee" two months prior to its 1894 annual convention. The following men were chosen: George H. Benzenberg (Chairman), L. H. Gardner, F. A. W. Davis and Edmund Mather. The committee's report, which was made at the 1894 convention, contained some very interesting data. Mr. Benzenberg again joined in the discussion following, by adding more information on the subject about Milwaukee.

19. The Electrolysis Committee of the American Water Works Association never did anything of any material value. Its function seems to have been limited to the discussion of various papers. Mr. Dabney H. Maury was its chief electrical adviser for many years. This committee was abolished a few years ago.

20. The following Twenty-seventh Annual Report of the City Engineer, of Boston, Massachusetts, dated 1893, was probably the first municipal report made upon the subject of electrolysis.

MILWAUKEE LABORATORY

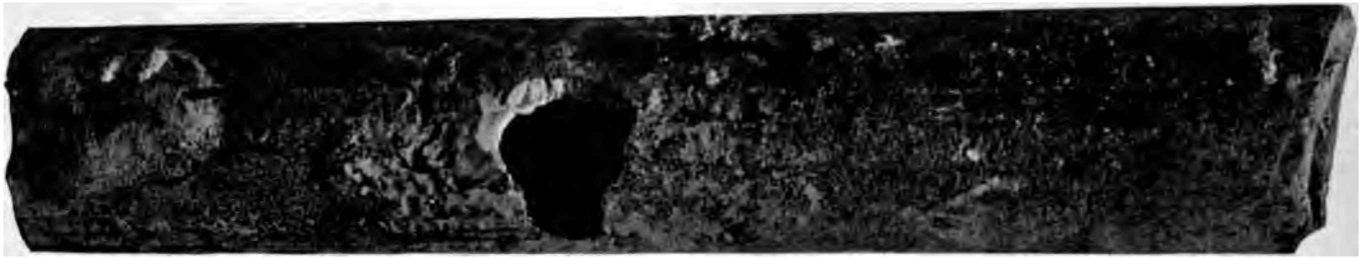
August 9, 1919.

Mr. H. P. Bohmann, Supt.,
Water Works & Water Purification, City Hall.

Dear Sir: The following is a report on the analysis of a sample of the earth which surrounded the water pipe that was decomposed by electrolysis (3-inch service pipe, Metropolitan Block, Third and State Streets.)

A microscopical examination of the earth compared to that of some cinders proved the absence of cinders or ashes in the sample.

The chemical analysis given below, shows the sample to be a mixture of loam and clay, owing to the fact that the loss on ignition is very high, thereby showing a high percentage of organic matter. The calcium and magnesium are present as silicates, which are poor conductors of electricity. The per cent of iron oxide is about the normal amount usually found in earths away from iron ore districts. The percentage of alkalies, soda and potash were obtained by difference. The presence of any other metals which is doubtful, such as



A 3-inch cast-iron water main leading into Metropolitan Block, Third and State Streets,
Milwaukee, Wisconsin. Destroyed by electrolytic action.
Laid September 14, 1890. Broke June, 1919

titanium, zinc, etc., and would have to be in very small amounts, probably .1 per cent or less.

From the above you can readily see that the earth itself around the water pipe cannot be considered of such a nature as to set up electrolysis by itself. The current more than likely was carried through it by the moisture.

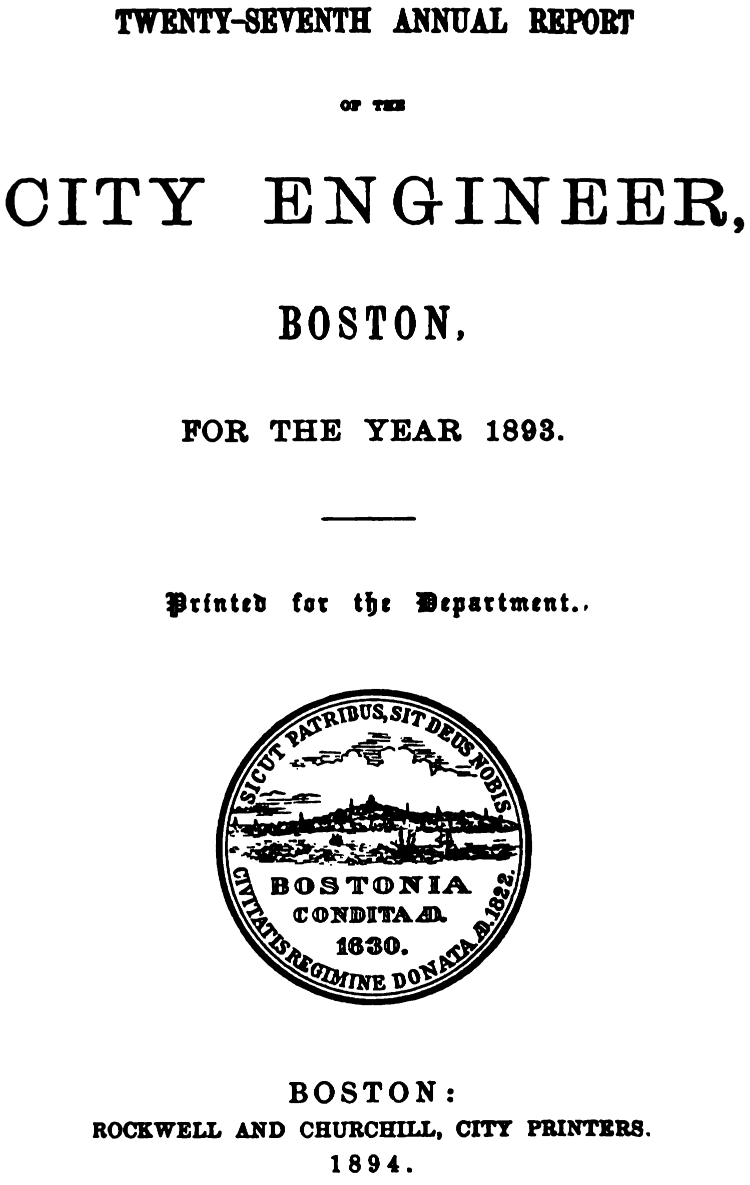
The chemical analysis is as follows:

Moisture	20.00
Loss on Ignition	20.80
Silica (Si. O_2)	26.60
Iron Oxide (Fe.$_2$ 0_3)	1.66
Aluminum Oxide (Al. $_2$ 0_3)	3.37
Calcium Oxide (Ca. 0)	18.35
Magnesium Oxide (Mg. 0)	8.57
Alkalies (Na_2 0 + K_2 0)	.65

Hoping this will prove satisfactory, I remain,

Very truly yours,

(Signed) ROBT. L. PIPER, Chemist.



TWENTY-SEVENTH ANNUAL REPORT

OF THE

CITY ENGINEER,

BOSTON,

FOR THE YEAR 1893.

Printed for the Department.

BOSTON:
ROCKWELL AND CHURCHILL, CITY PRINTERS.
1894.

FROM THE CITY ENGINEER'S REPORT TO THE BOSTON WATER BOARD

CORROSION OF PIPES BY ELECTROLYSIS.

During the year 1892 a number of leaks in lead service-pipes were found which were caused by electrolytic action due to underground currents of electricity induced by the street-railway system

The pipes were decomposed on the exterior surface and presented a pitted appearance. Most of the cases were discovered in the immediate vicinity of the power-station of the West End Railroad Company, where the quantity of current is naturally largest.

As the use of electricity for motor power is constantly increasing, and as the destruction of our water mains and services would be of incalculable injury to our city, an investigation has been begun into the causes and extent of the difficulty, with the view of taking the necessary measures to preserve the pipes, both lead and iron, from further injury. This investigation has been placed in the hands of Messrs. Stone & Webster, electrical engineers, and the results of their preliminary study indicate that decomposition of the pipes is going on, but that, generally, it may not be apparent for some years.

The cases which have so far been discovered have been where the quantity of electricity in the ground was large; but we have no proof that the same action is not taking place more slowly all over the city. The investigations show that there is a constant current of electricity flowing through the earth toward the power-station, and that the intensity of the current varies continually with the amount of power used. As these currents must unavoidably pass into and out of the water-pipes by way of the earth, and as electrolytic action follows in a greater or less degree, it is more than probable that the gradual decomposition of our pipes is taking place.

Whether this corrosion of decomposition is sufficient to seriously affect the pipe system has not yet been determined, and I recommend that the investigations be continued during the present year. I would also recommend that test-pits be dug for the examination of the pipes in different parts of the city, particularly in the immediate vicinity of the West End power-station, and if evidence of corrosion of the pipes is discovered I would recommend that the pipes be drained by means of heavy copper conductors connected with the power-station.

The following is a preliminary report from Messrs. Stone & Webster:

BOSTON, January 31, 1894.

WILLIAM JACKSON, Esq., *City Engineer:*

SIR: In accordance with your request we have entered upon a careful investigation of the subject of the corrosion of water pipes and mains by electrolysis, and beg to submit the following preliminary report:

A longer time for experimental work, and a season of the year at which the pipes are more freely accessible, are necessary to place us in a position to report fully on the extent of the difficulty, and to make definite recommendations as to its remedy.

This report presents briefly to your consideration the following points, and contains an appendix which includes various data obtained by us, together with a somewhat detailed discussion of the same

The points considered in this report are as follows:

First. The evidence showing injury by corrosive electrolysis to underground iron and lead piping for water, gas, and telephone cables in Boston and elsewhere.

Second. The nature of this injury to pipes as developed by experimental tests in the laboratory.

Third. The existence of the necessary conditions, electric and otherwise, in the soil of Boston, to produce electrolysis in pipes laid therein.

Fourth. The proof that these electric conditions are due to the return currents by way of the earth, arising from the electric service of the West End Street Railway Company.

From these we shall show that the inference that serious corrosion may be proceeding from this cause is almost unavoidable, while, however, distinctly pointing out that the evidence is still insufficient for decisive judgment.

Finally, while we are not yet prepared to suggest a practicable and complete remedy, we shall point out methods by which the trouble has been somewhat lessened in certain instances.

The Evidence of Injury.

The action of electrolysis is to corrode the pipes, chiefly at the surfaces where the electric current leaves them. This corrosion is not uniformly distributed over the surface, but is quite irregular, usually producing deep pits. Its tendency is, therefore, to accelerate the natural rate of decay of the pipes, the rate of corrosion being greater as the current flowing out of the pipe is greater.

The evidence of injury to water and gas mains by electric action would, therefore, naturally be expected to take two forms: one, the very premature giving out of pipes in localities where the conditions were such that especially large currents flowed out from the surface of the pipes; the other, the increase of rate of renewals and repairs in the entire system, so far as exposed to the electric currents.

Evidence of the first sort would presumably be the earliest to develop itself, and we shall quote some instances. Evidence of the second sort would appear only in the course of years, and the evil might have assumed serious proportions before this class of evidence became convincing. We have been able to secure very little such evidence.

It should be clearly apprehended that the injury to the pipes, if going on at all, is of a very insidious character, consisting, as stated, merely in an acceleration of the natural decay of the pipes. This acceleration might be seriously large and yet not become apparent for a term of some years, when the trouble would suddenly begin to assume very large proportions. The absence of extensive direct evidence of destruction must not, therefore, be interpreted as proving the absence of the action. The amount of direct evidence, although not yet large, is sufficiently disquieting.

Of actual[1] giving out of water-pipes in Boston, apparently through electrolysis, the only instances which we are able to cite are those of lead service-pipes in the vicinity of the power-station of the West End Street Railway Company on Albany street. At the time that these pipes were discovered, the subject was not under careful investigation, and the reasonable supposition that electric currents played a considerable part in their destruction was not put to test by critical inspections.

Of the destruction of lead piping in general by electrolytic action underground, we have abundant and indisputable evidence in the corrosion of the lead sheaths of telephone cables. In one case, the sheath of a new cable was destroyed within six weeks of laying. The amount of the injury, its nature, and the methods successfully adopted for its partial removal, show conclusively that it was due to electric currents traversing and escaping from the lead covering on their way between the electric cars and the power-station of the West End Street Railway Company, in the same way that they presumably do from water-pipes.

From several cities other than Boston, owing possibly to more favorable conditions for the development of trouble, injury of a serious nature has been reported respecting water and gas mains. We have information, reliable in character, showing electrolytic injury of water-pipes in Peoria, Ill., and Cambridge, Mass., and of iron mains in Norwalk, Conn., — the trouble being serious in all cases.

Pipe-Tests.

In order to get an idea of the probable character of the electrolytic action upon the water-pipes and the rapidity with which it might be taking place, a number of tests were made at our laboratory upon commercial specimens of pipe, under conditions similar to those to which the city piping is exposed.

The pipes were grouped in pairs as shown by the table of pipe-tests and each pair in a separate box of moist sand sprinkled with a small quantity of common salt.

In this respect they were practically under the conditions of pipes buried in the streets, since the moist earth usually contains common salt and other salts either from the tide water or from the surface drainage.

Measured currents of electricity at constant pressure were then caused to flow for noted times from one pipe to the other of a pair. Thus one pipe would show the action when the current flowed out of the pipe into the earth (*i.e.*, when the pipe was electrically positive with respect to the earth around it); the other would show the effects when the current flowed from the earth into the pipe (*i.e.*, when the pipe was negative relatively to its surroundings).

The common salt in the water by its electrolysis yields chlorine at the surface where the current of electricity leaves the pipe. This corrodes the pipe rapidly. At the surface where the current enters the pipe the product formed by the electrolysis has but little corrosive action.

This well-known fact was borne out by these experiments, which developed, moreover, a point of great practical importance; namely, that the corrosion took place largely in a localized manner. That is, the pipes became deeply pitted in spots instead of corroding uniformly over the surface.

Although the difference of potential between every pair was the same, the currents were of various magnitudes corresponding to the degree of moisture and quantity of salt in solution.

Consequently, this must be taken into consideration, in comparing the effect of electrolysis on pipes in different boxes; for with pipes of the same material, the losses are directly proportional to the magnitudes of the currents. After reweighing at the end of 100 hours, the tests were continued for 50 hours more on all the specimens except Nos. 13 and 14.

The positive pipes were all badly pitted, so that the amount lost as determined by weighing before and after the run is not a true measure of their deterioration

To make this more evident, pipe No. 13, which had lost but 7.6 per cent. in weight, was turned down for half its length, to the bottom of the deepest pit, and the loss in weight was then found to be, for the whole pipe, 63 per cent. This shows, of course, that owing to the formation of pits the corrosion has gone in spots to about eight times the depth that it would have gone if it had been uniform over the surface.

This is a true measure of the electrolytic action, for the strength of a pipe is determined by the strength at its thinnest part, which leaves the pipe but 37 per cent. of its original value.

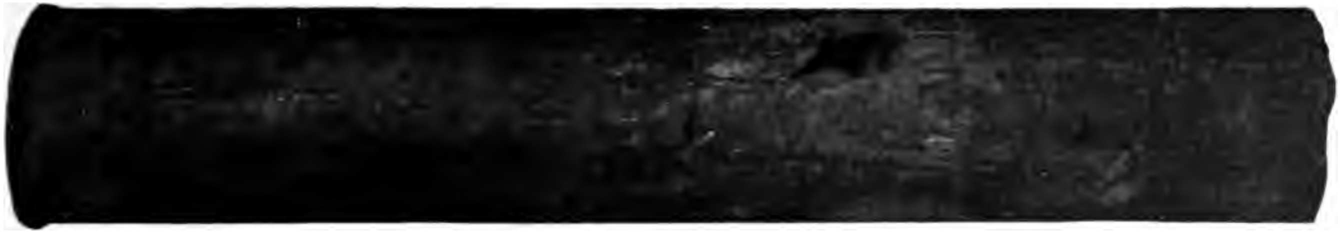
Tarred Wrought-Iron Pipe No. 13.

Length	1	foot
Diameter	1	inch
Original weight	694.7	grams
Loss of weight after 100 hours	53.2	"
Average current	0.739	amp.
Average voltage	12.96	volts
Weight of iron turned off in ½ length	191.9	grams
Weight of iron pipe equivalent to pipe in present condition	257.7	grams
Present value in per cent. of original	37	per cent.

After running one hundred and fifty hours, four other iron pipes, Nos. 1, 5, 9, and 11, were similarly treated, and the results tabulated below. The positive lead pipes were all so deeply pitted that it was impossible to turn them down. They showed even more marked deterioration, however, than the wrought-iron pipes.

A 6-INCH CAST-IRON WATER MAIN ON THIRD STREET SOUTH OF CHERRY STREET, MILWAUKEE, WISCONSIN.
DESTROYED BY ELECTROLYTIC ACTION. REPLACED NOVEMBER 20, 1919.

(Reprinted by E. E. Brownell)
(December 1, 1919)



AN 8-INCH CAST-IRON WATER MAIN ON WALNUT STREET AT INTERSECTION OF THIRD STREET, MILWAUKEE, WISCONSIN. DESTROYED BY ELECTROLYTIC ACTION. REPLACED NOVEMBER 28, 1919.

[illegible]

Table showing True Extent of Deterioration caused by Electrolysis.

Number of pipe	1	5	9	11
Length	1 ft.	1 ft.	1 ft.	1 ft.
Diameter	2 in.	1 in.	1 in.	1 in.
Original weight in grams	1,565.3	693.0	638.0	695.0
Loss of weight in 150 hours	39.7	172.8	202.2	129.2
Average current	0.253	1.420	1.472	0.946
Average voltage	12.37			
Weight of pipe equivalent to pipe in present condition	850.6	169.6	199.6	161.2
Present value in per cent. of original	54.3	24.5	31.3	23.2

In these tests data have been accumulated which may prove of further value later in a discussion of the relative merits of different kinds of piping, but which we are not now prepared to enter upon.

In the experiments, in order to save time, it was necessary to use currents of electricity larger than could be expected to occur, except under unusual conditions, in practice. This, however, does not affect the general character of the electrolytic action, but only its rate, the amount of electrolysis being proportional to the current.

The corrosion and disintegration of the sheaths of the telephone cables by electrolysis underground was of the same general character as that in the lead pipes tested in the laboratory.

Existence of Necessary Condition for Electrolysis.

If we could ascertain by direct means whether currents of electricity were flowing from the earth into the pipes or from pipes to earth, how large these currents were, and how they were distributed over the pipe surface, we should then have a direct means of estimating the injury done to the pipes; but these three points are from the nature of the case very difficult, if not impossible, of even rough determination. It is essential, therefore, to proceed indirectly by showing that the underground electrical conditions in the city are such as either to render destructive electrolysis likely, or to render it unlikely. We have done so as follows:

By extended tests we have shown that the distribution of electrical pressure in the earth in Boston is such that there must be a continual and at times strong flow of electricity through the earth from nearly all parts of the city toward the West End Power-Station on Albany street.

Inasmuch as iron water and gas mains are imbedded broadcast in the soil, and are relatively much better conductors than the soil, bulk for bulk, a portion of these currents must traverse the pipes: and since there is no metallic connection between the pipes and the railway returns, the current must enter and leave the pipes by way of the earth. Wherever the current thus enters or leaves a pipe it is accompanied by electrolysis at that point, the amount of the electrolysis being proportional to the current. This produces corrosion, but chiefly where the current leaves the pipe.

Admitting, then, the conclusion just drawn that currents must enter and leave the pipes, and since this process is nearly continuous throughout the day, the inference is unavoidable that corrosion is continually going on, and in the same measure as the current. This inference is confirmed by multiplied tests, which show that the piping is almost everywhere at a potential different from the earth around it, and from the nearest railway tracks.

Under such conditions currents must be flowing either to or from the pipes. These differences are, moreover, not constant, but subject to continual momentary fluctuation, which add to the certainty of the flow of currents.

The demonstration of the continual flow of current through the earth to the power-station was made by measuring the difference between the electrical pressure in the water-piping at a point near the station, and at other distributed points. These outlying points showed always higher pressures than the one near the station. The difference amounted in one case to more than 15 volts in 4,000 feet. Similar measurements were made between the outlying points themselves.

It is evident that by taking a sufficient number of points and of pressure observations between them, an equipotential map — that is, a map showing lines of equal pressure difference relatively to the power-station — might be drawn; but while such a map would possess some value, we have not yet thought ourselves justified in incurring the expense of running the necessary number of overhead lines in the city.

It is, perhaps, not superfluous to add that the substances which give the soil its conductivity are chiefly the various salts which are in solution in the water of the soil. Earth itself, when perfectly dry, is a very poor conductor; water when pure is also an exceedingly bad conductor. Moist earth is usually a comparatively good conductor, not, however, because of the conductivity of the water itself, but because the water holds in solution common salt and other salts which make it a conductor, these being derived either from the soil, from surface drainage, or from the sea, much of the soil beneath Boston being moistened by tide water.

There are, therefore, present in the soil of Boston not only the electric current necessary to produce electrolysis, but the materials which will upon electrolysis produce corrosion of iron and lead.

Cause of the Underground Electric Current.

The above-mentioned measurements of pressure-difference between various points afford convincing proof that these pressures are due almost exclusively to the return currents of the West End Street Railway. For not only are the pressures found to be distributed about the power-station in the way which would be anticipated, but they show fluctuations from hour to hour, and even minute to minute throughout the day, which, when plotted as curves, show the characteristic form of the power load at the station, being nearly zero in the early morning hours, and having four maxima; namely, at about 8 A.M., 6, 8, and 11 P.M. This point is very clearly illustrated by tests made on January 3d and 4th, 1894, to show the difference of potential between the water-pipes at different points in the city. By means of rubber-covered copper wires the water-pipes at Foster's wharf and Summer street were connected with the water-pipes at the corner of Harrison avenue and Bristol street, near the power-station of the West End Street Railway.

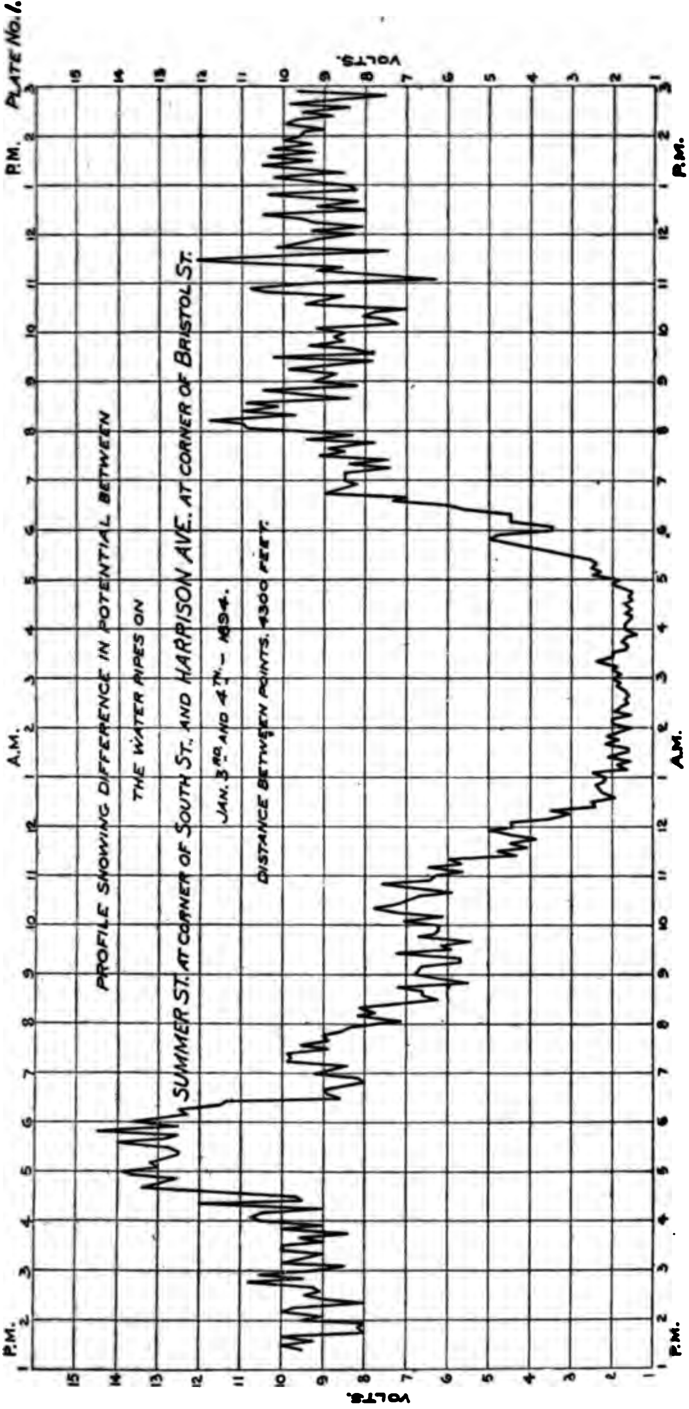
Continuous readings of the difference in potentials were taken for 24 hours, and the results show admirably the periodic fluctuations corresponding to the amount of travel on the railroad. (See plates 1 and 2.)

If any evidence of the source of these currents and pressures were necessary, this would be incontestible.

Summary.

It seems from the preceding discussion that the direct evidence is good, although not yet ample; that injury has been wrought upon iron and lead pipes buried in the earth; this injury being the direct result of corrosion arising from the passage of the return currents of an electric street-railway into or out of the pipes.

BOSTON, MASSACHUSETTS



BOSTON, MASSACHUSETTS

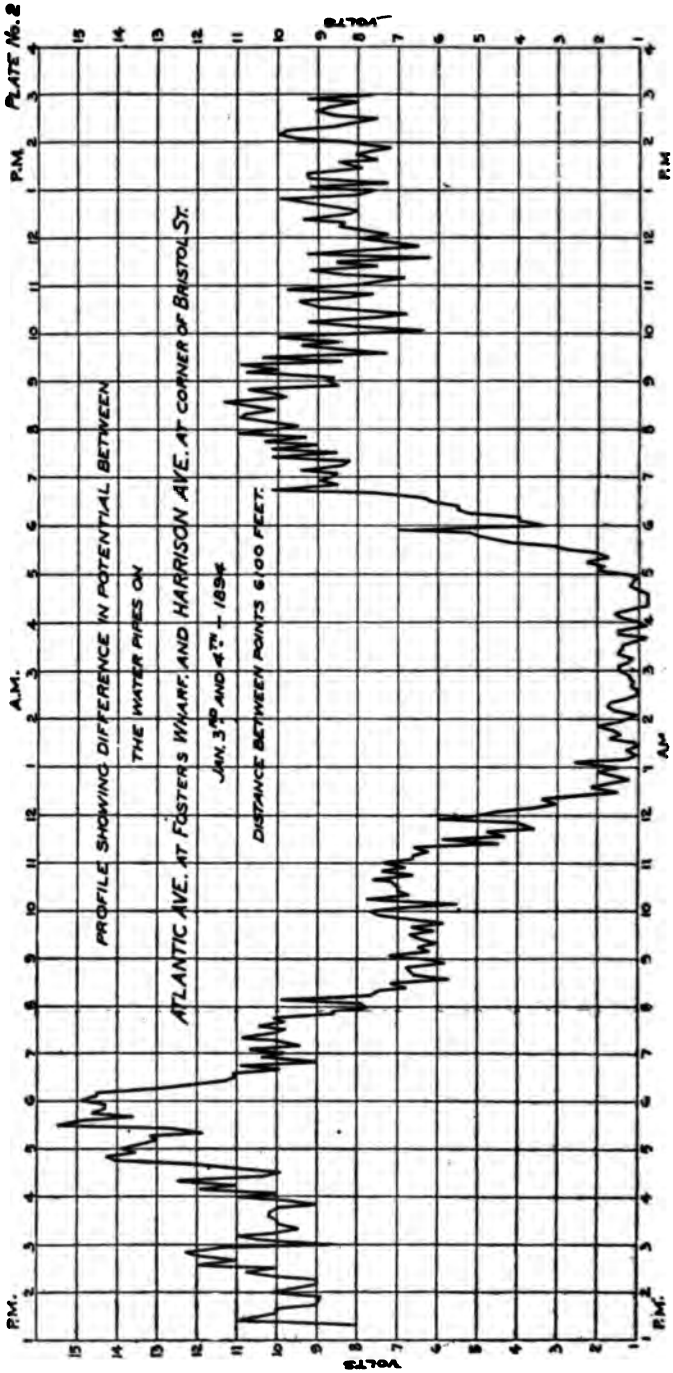


PLATE No. 2

PROFILE SHOWING DIFFERENCE IN POTENTIAL BETWEEN
THE WATER PIPES ON
ATLANTIC AVE. AT FOSTERS WHARF, AND HARRISON AVE. AT CORNER OF BRISTOL ST.
JAN. 3RD AND 4TH — 1894
DISTANCE BETWEEN POINTS 6100 FEET.

It seems further to be almost incontestably shown that the underground conditions in Boston are such that electric currents, presumably of considerable magnitude, pass into and out of the pipes by way of the earth, and with the unavoidable accompaniment of electrolysis and corrosion.

It remains to be shown whether this corrosion is or is not, under existing conditions, a serious factor in lessening the life of the piping system as a whole or of any part of it in particular.

Upon this most important subject we feel that the points previously made in this report would certainly not warrant a hopeful view. They would rather incline one toward the opinion that serious corrosion may be now proceeding; but we must strongly call attention to the fact that it has been impossible, thus far, to acquire sufficient reliable information to warrant a decision.

The matter is under further investigation.

Remedy.

As to remedy it is clear, of course, that were the return railway circuit to be confined to channels provided for it, the trouble would cease This it is impossible to do with a railway system in which the cars give up their return current to the uninsulated rails as now. However good the conductivity of the copper return lines provided, the current will divide between them and the earth, the fraction going back by earth being to that going back by the copper lines as the earth conductivity is to that of the lines. Now, the earth conductivity is at least fairly good, so that the amount of copper required in returns becomes enormous to reduce the earth currents to small amounts. Railway systems which do not ground the return have not proved successful for various reasons.

To remove the difficulty with telephone cables, the New England Telephone & Telegraph Company has laid a special copper return along the affected part of the cable, and thence by a heavy overhead line back to the power-house. This, together with the practice by the West End Street Railway Company of making the trolley-wire positive, has proved largely successful.

It is feasible because the number of these cases to be dealt with is comparatively small, so that the expense is not intolerable.

A similar suggestion respecting certain portions of the water-main system was offered by us in February, 1893.

The larger and better distributed such a system of special copper return from the water-pipes is, the less danger from electrolysis; but the great outlay for copper involved is prohibitive beyond a certain limit. Whether within this limit the electrolysis can be reduced to an unimportant amount is by no means yet demonstrated. The data is still so incomplete as not to warrant a positive inference.

(Signed) STONE & WEBSTER.

21. The Twenty-sixth and Twenty-seventh Annual Reports (1894-1895) of the Board of Public Works of Poughkeepsie, N. Y., contain many interesting and early features.

PART VII

VARIOUS ELECTROLYTIC SURVEYS ON MILWAUKEE WATER WORKS

1. On August 8 to 22, inclusive, 1900, E. E. Brownell made a Electrolytic Survey of the Milwaukee Water Works. This surve was made at the same time that a similar one was being conducte in connection with the Milwaukee Gas Light Company. The 19 survey was followed by others, made by the writer, December, 190 November, 1902, and again in November, 1905.

2. The entire electric street railway system, in the City of Mi waukee, as relating to the Milwaukee Electric Railway and Lig Company, was then fed from one principal powerhouse. It was th Oneida and River Street Station. There was, however, a temporar station at Kinnickinnic Avenue and Mitchell Street, or thereabout in 1892-3.

3. There were no substations for electric street railway dist bution purposes at this time. The Milwaukee Electric Railway a Light Company at this time (1900), was the only source of ground electric circuits in the City of Milwaukee.

4. In August, 1900, there were over 25 miles of water main positive to the tracks of The Milwaukee Electric Railway and Lig Company. This did not include many miles of cross lines that wer being subjected to more or less serious electrolytic corrosion.

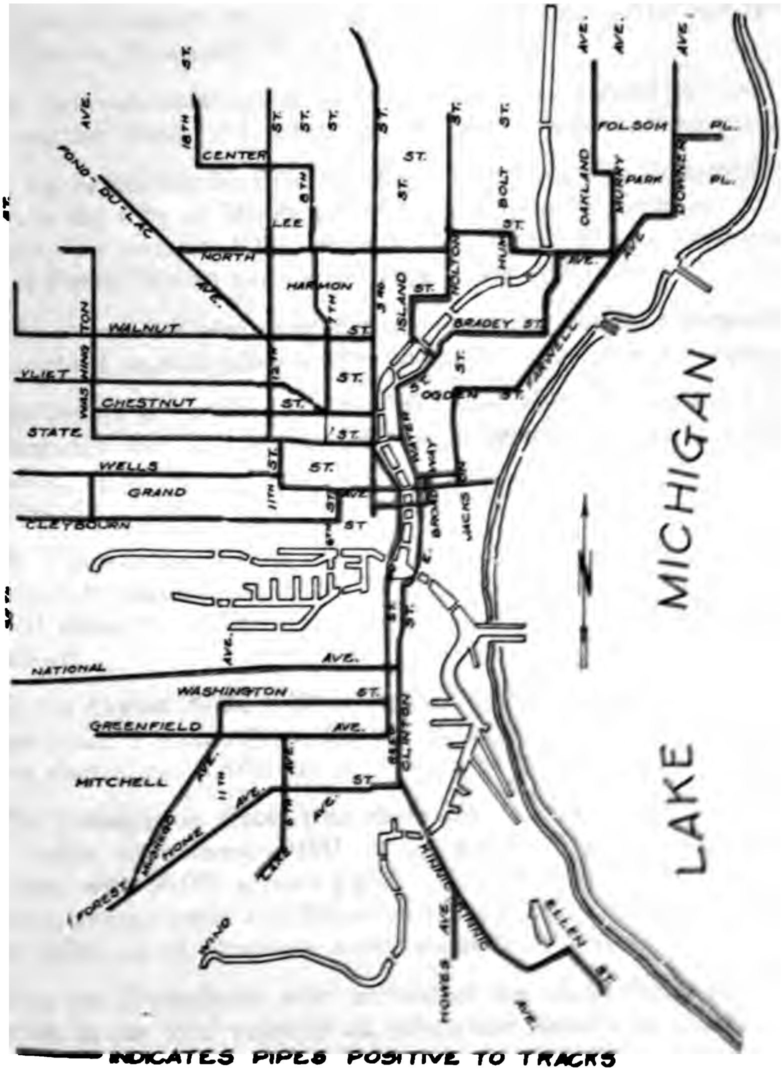
5. When considering the electrolytic conditions, as a whol throughout the City of Milwaukee, as found upon the Milwauke Water Works System, from August, 1900, to November, 1905, th writer is forced to say that they were serious and very widesprea although not extremely acute in any one particular locality.

6. The writer's conclusion at that time (1900-05), was that som one in connection with the operation of The Milwaukee Electric Rai way and Light Company, was making every effort to scatter th menacing electrolytic conditions, rather than to have them more loc and acute. This operative policy has always appeared to the writ in this light from 1900 to 1919, inclusive.

7. In 1910, C. R. Pierce made a report to the Wisconsin Rai

ELECTROLYTIC CHART
OF
MILWAUKEE WIS.

RECORDED AUG. 8-22, 1900 BY E.E. BROWNELL, B.E.E.



—— INDICATES PIPES POSITIVE TO TRACKS

━━ INDICATES PIPES NEGATIVE TO TRACKS

pages 8 and 9 of this (1912) report, as the Pipe Drainage System, for electrolytic protection is severely criticized by him.

The Railroad Commission of Wisconsin never did anything material toward carrying out the recommendations of the 1910 or the 1912 report made to them.

10. On June 7, 1915, Frank K. Brainard, assisted by Messrs. H. N. Bartling and Ray P. Mattern, made an Electrolytic Survey of the City of Milwaukee.

Mr. Brainard finally recommends the "Pipe Drainage System" as the best means of protecting the Milwaukee Water Works System against electrolytic corrosion.

This report, though not very lengthy, is the work of one who knows considerable about the real practicability of the subject.

It has many excellent features, and for this purpose was printed (by the writer) and made a part of this report, with photographs attached. (See pages 5, 6, 7 and 8 for final recommendations, in Mr. Brainard's report.)

11. An extensive Electrolytic Survey, made by E. E. Brownell in April, 1917, upon the Milwaukee Water Works, showed that the electrolytic conditions then (1917) were more serious upon the water system than at any previous period known to him.

Most of this information will not appear in this report, on account of the threatened litigation between the City of Milwaukee and The Milwaukee Electric Railway and Light Company.

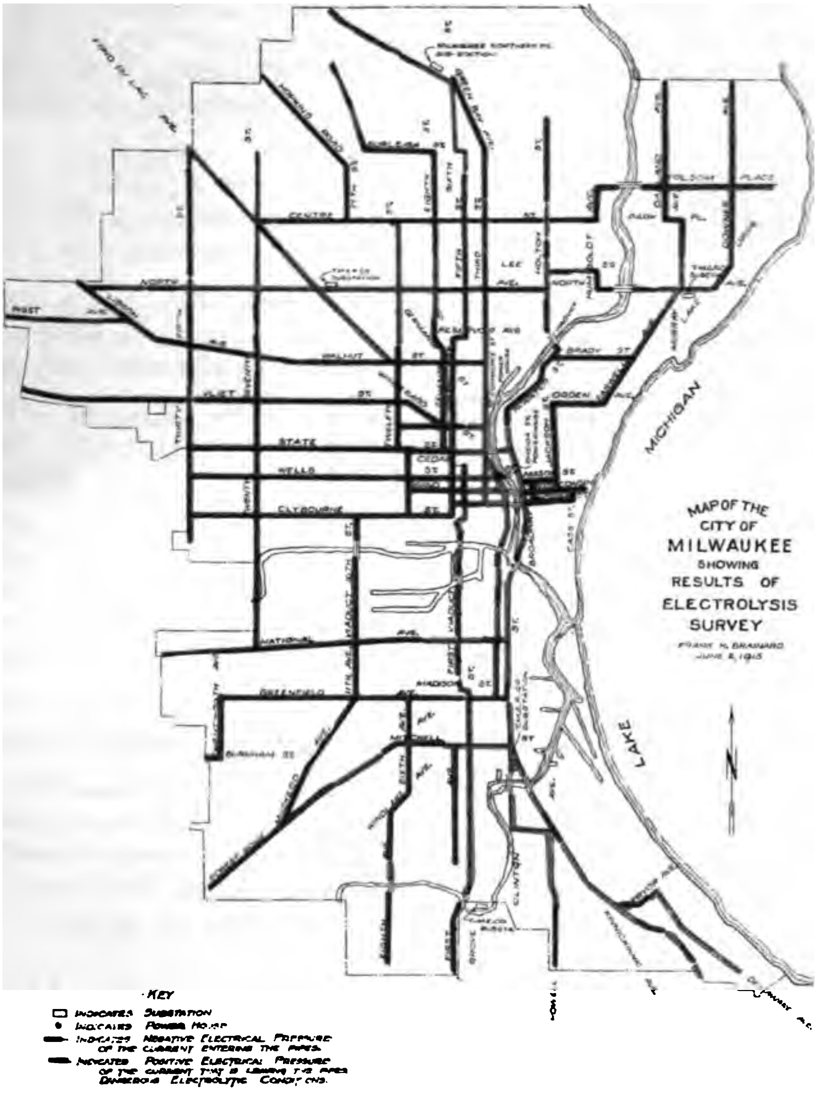
Nevertheless, the writer, knowing certain electrolytic conditions in the City of Milwaukee, from 1900 to 1919, as affecting the Milwaukee Water Works System, is thoroughly convinced of the great destruction that has taken place, and that is in all probability still continuing.

The injury is irreparable, and to the best knowledge and belief of the writer, has appreciably damaged more than $500,000.00 worth of cast-iron water mains belonging to the City of Milwaukee.

This statement by the writer can be very easily proven, by appropriating about $25,000 for physical inspections of the damaged pipes.

Scientific research work along this line has made this proof very easy.

Reproduced from original by E. E. Brownell, B.E.E. Phila. Penna. June: 1919



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'he Milwaukee Electric Railway and Light Company has known
:riousness of this electrolytic condition since 1893. In 1900 the
· called upon Mr. John I. Beggs, and discussed the subject
with him, at that time, in his Milwaukee office.

[r. Beggs took the position that the "public be damned" policy
he only way to combat the claim of damages from electrolysis,
as his company (The Milwaukee Electric Railway and Light
any) was concerned.

he public policy of The Milwaukee Electric Railway and Light
any, and that of Mr. John I. Beggs included, has been the most
nptible one noted by the writer in his 26 years' experience with
service corporations throughout the United States.

: is a disgrace for them to be operating this property, for they
nothing in common with the public of the City of Milwaukee,
: that which will advance their own selfish ends.

his deplorable state of affairs has done much to retard the
y and natural growth of this great municipality, the City of
ıukee.

or a community to prosper, the municipality and the public
e corporations must co-operate and grow together. If the
service corporations will treat the public fairly, they will in
t every case receive, in return, equally fair and considerate
ıent.

'he plea that there are no available funds for the installation of
:quisite electrolytic mitigative measures, is no excuse.

ı the balmy days of The Milwaukee Electric Railway and Light
any, years ago, was the opportune time to have begun treating
ıbject with due care and proper consideration. They should not
waited until the eleventh hour arrived, and then pleaded the
›f funds in extenuation of almost criminal neglect.

ELECTROLYSIS OF UNDERGROUND PIPES

(From the Engineering Record, New York, October 14, 1893;
London, October 28, 1893)

)uring the last three or four years a growing dread of the elec-
street railway has been marked among companies which are
ed to have pipes underground near the tracks of such roads. This

feeling is equally strong among the gas, water, and telephone interests, and that there is ground for it has been amply proved in many cities in the United States, England, Germany, and France. The gas and water companies in Cambridge, Mass., were among the first to make a scientific investigation into the matter in the United States, although pipes and mains destroyed by stray electric currents had been dug up in other cities some years previously.

In Cambridge the problem was attacked by Hiram Nevons, Superintendent of the local water-works, C. H. Morse, city electrician, H. A. Allyn, of the local gas company, and F. S. Pearson, the electrical engineer of the West End Street Railway Company. The conditions in that city were anomalous at the time the trouble was first noticed. The railway company in building its lines laid a wire along the center of each track and connected the rails on each side to this wire. As the road was then operated the electric current left the positive poles of the dynamos, flowed through the large feeder cables to the trolley wires, from the trolley wires down the trolley arm to the wiring of the cars leading to the motors, and from the motors through the rails and this underground wire back to the negative pole of the dynamo. After a time, however, trouble arose. It was found that the return wire, originally the size of a lead pencil, corroded away in places, especially if the earth was moist. When a rail was left without connection by corrosion in this manner, and a man touched it with one foot while the other was on the ground, he would receive a shock if a car was near. The railway company experimented for some time on the matter and then completely changed the conditions of operation on its lines. Current was sent from the dynamos through the former return circuit to the cars and then back through the overhead trolley wires and feeders. As soon as this change was made there was trouble among the gas and water pipes. Lead pipes disappeared in six or eight weeks, brass pipes corroded as soon as laid, iron pipes, even when galvanized, deteriorated rapidly, and rustless iron belied its name. Mr. Morse states that there was no corrosion except at the positive poles where the current left the pipes, and this is the case in over half a dozen cities where electrolysis has since been marked. The destruction of pipes was so marked that the railway company decided to return to its old method of supplying current through the overhead wires and allowing it to return through the ground, and since this method of operating has been in force the trouble has diminished.

The nature of the electrolytic action is really very simple and the phenomenon itself has been known for several hundred years. Mr. Morse has explained it very well in essentially the following words: A difference in potential of two volts in a current flowing from one piece of metal to another through moisture causes the decomposition of water. The water separates into two gases, oxygen and hydrogen, at this place. The former gas attacks the pipe, pitting and eating it until finally it is destroyed for practical purposes. The remedy is obviously to connect the pipe or cable with a metallic circuit leading back to the powerhouse. In Cambridge this is done by heavy copper wires leading from the water pipe. Unfortunately, as soon as this was done the electricity was attracted from the gas company's mains to the more highly conductive water pipes and thus the gas mains were injured. Finally it was decided to connect the gas mains and water mains together in every building by soldering copper wires between them. That this was necessary the following incidents, given on the authority of Messrs. Morse & Nevons, show pretty conclusively:

> Such an amount of current was flowing over the pipes that upon attempting to make a joint by putting oakum around the pipe, it was found at times that the electric arc was often sufficient to set fire to the oakum. This did not necessarily indicate a very high potential but proved the presence of a large quantity of current in the earth. This is indicated also by an experience at a new engine-house in East Cambridge. There was an old and a new water main leading into this station and when they were connected by a medium size wire it was heated so hot that the hand could not be placed upon it.

The experience of Milwaukee, Wisconsin, was similar in many respects. City Engineer George H. Benzenberg recently stated that about a year ago a service pipe leading from a water main into a power station of the local electric railway was found to have corroded entirely away. It was replaced by a second pipe which very soon began to leak also and three months after it was laid broke entirely. Upon examination one length of it was found to have gone entirely and another to be pretty well corroded and eaten out. The metal was so soft and spongy that the end of a cane could be poked through it, but after removal from the ground it became hard again. The railway company had been connecting its ground wire with the fire hydrants, and about 200 such connections had been made without Mr. Benzenberg's knowledge. The current apparently did no harm to the hydrants, mains, or pipes until it left the pipe at a point opposite the station to reach the dynamos. Here the pipe was corroded as already mentioned. To remedy the trouble a copper conductor has now been attached to the mains near each powerhouse and led to the generators located in them. The same phenomena have been noticed in Brooklyn, N. Y., Columbus, Ohio, Indianapolis, Ind., Sault Ste. Marie, Mich., Hamilton, Ont., and other American cities, and everywhere the trouble seems to occur at the points where the current leaves the pipes, as would naturally be expected by the analogous phenomenon in electroplating.

From the experience gained in the above cities it is apparent that the electrolysis is largely due to the lack of a metal return circuit of sufficient conductivity between the cars and the dynamos, and it is now pretty generally admitted that railway companies will find it more profitable to make a good return circuit than to force their return current through the earth. Some engineers estimate that from 5 to 20 per cent of the current is lost on this account, the percentage varying with the conductivity of the earth, but it is possible that such estimates are over the actual amount. Still it has been the practice until recently among the most advanced electricians to add 20 per cent to the weight of copper feeders to allow for earth and rail resistances, this addition being made on assumed conditions. Although this has been the best practice many have assumed that the earth-rail return offered no resistance, even without bonds connecting the separate rails. Recently some measurements have been made by R. L. Warner and G. L. Thayer, which give some definite information on the subject. The full report of these experiments can be found in the "Electrical Engineer" for 1892, but the following figures give the results of most interest to engineers working on electrolysis. The resistance per mile of double-track road was found to be 0.7675 ohm in dry earth without bonds connecting the rails. Where the rails were bonded with iron wire of No. 3 gauge and cross-connected without a continuous return wire the resistance was 0.0797 with dry and 0.0717 ohms with wet earth. Where the track was formed with No. 3 copper wire bonds riveted to the rails, each bond soldered to a continuous copper wire of the same gauge and the rails cross-connected every 200 feet the resistance was 0.0207 ohm with wet earth. When the track was made in the same way as in the last example, but further improved by soldering the riveted bonds to the rails and spacing the cross-connections closer together, the resistance when the earth was dry amounted to 0.0254 ohm. Track bonded with two No. 4 galvanized-iron wires without a continuous return wire had a resistance of 0.0577 ohm when the earth was dry.

These figures are very instructive and confirm, so far as the go, the assumptions made by Lieutenant Crosby, Dr. Bell, and othe engineers. They show that some bond is necessary, and furthermore that the resistance of the rail section is so slight that the calculated resistance of the bonds accounts for nearly all of that observed. This suggests a practical point—namely, the desirability of making the bonds larger than is now the usual practice and omitting the return wire. The effect of this wire has long been generally acknowledged to be small and its value to be chiefly as a supplement to the bonds. There is a strong tendency now to do away with it entirely. It increases the conductivity of the return circuit somewhat, but probably not as much as if the metal in it were used to make larger bonds. A Johnson section 80, No. 254, girder rail for example weighing 80 pounds per yard, has about the same conductivity as a copper wire 1¼ inches in diameter, while a section H, 60-pound Lewis and Fowler box rail has about the same resistance as a copper wire 1⅛ inches in diameter. No such amounts of copper have yet been used to make bonds, and until they have the possibilities of rail returns have not been exhausted. If the copper in the return wire in the third kind of track mentioned in the last paragraph were placed in the bonds the latter would be over an inch in diameter instead of 0.23 inch, and the actual conductivity of the return over thirteen-fold greater.* This shows that water, gas, and telephone mains can be protected by better track construction, which will prove as advantageous to the railway company as to the other interests. This is one of the means of protecting mains from electrolysis, and suggests the following as a second method, which in most cases can probably be applied without much trouble.

This second method is merely the connection by metal circuits of the water mains, gas pipes, and telephone cables, to which some electricity will probably always pass, with the generators at the points where there is the least resistance to return currents. These are not ecessarily the points where the distance between the pipes and the nerators is the shortest, for it is possible to have this shortest line rough dry sand and a line nearly a few hundred feet longer through ist earth with less resistance. The electricity of the return cur t would be apt to leave the pipes at the moist places under such ditions, and it is possible that the return metal circuit should be

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Since the above was written Thomas J. McTighe, electrical engineer e Atlantic Avenue Railroad Company, of Brooklyn, presented a paper the Street Railway Association of New York recommending this con ion. Comment on the subject will be found in the editorial columns.

located here, although somewhat longer than at another point. Old rails, heavily bonded, have been suggested for such a use, and would probably prove satisfactory.

RETURN CIRCUITS AND ELECTROLYSIS

(From the Engineering Record, New York, October 14, 1893;
London, October 28, 1893)

The matter of the electrolysis of pipes and cables by the return currents of electrical railways is probably destined to play such an important role within a few years, if steps to prevent it are not taken, that an outline of our definite knowledge on the subject is given in another column. The whole question is of course dependent on the return circuits of the electric railways, for if these are of such conductivity that the current will return through them to the power-station then there will be no wandering electricity to get into the pipes of the water works or gas plant and give the unfortunate manager several uneasy hours of investigation.

If the electric railway managers can be convinced that the remedy for this electrolysis lies in their power and will actually be to their advantage to apply, then the matter will be in a fair process of solution, indeed in a much better state than when it is believed that expensive insulated return circuits are necessary to prevent the trouble. The conclusions reached by "The Engineering Record" some time ago are given in another column. From these it will be seen that railways on a large scale are now in operation which are provided with return circuits such as we believe will largely reduce electrolysis, and the much better return circuit of such roads was provided at a less cost than the hitherto adopted practice.

It is now the general custom to connect the adjacent ends of rails with bonds and to connect the rails with a wire or wires running back to or nearly to the power station and placed between each pair of rails. Theoretically, the current is supposed to return through these wires and bonded rails, but practically the resistance of the metal circuit is so much less than the resistance of the earth that, as soon as the latter becomes a trifle damp, the electricity deserts the roadway and passes through the earth to the excellent circuit provided by the water and gas mains or the lead covering of the telephone cables, traveling along these conductors until there is a better conductor elsewhere, when it goes to that conductor and leaves as a mark of its presence a little pit in the metal at the point of departure.

The trouble is that the return circuit through the track does not have the conductivity of the earth and pipe circuits.

The return circuit can be given an excellent conducting capacity, however, if the method now followed on the Atlantic Avenue Railway in Brooklyn is adopted. Here special advantage of the conductivity of the rails is taken by the engineer, Thomas J. McTighe. A 70-pound rail is used, so that the area of the four rails in the track is practically 28 square inches, which has the conductivity of 4 2/3 square inches of copper. Track with such rails and under similar conditions of usage has generally been laid with No. 4 copper bonds and two No. 0 copper supplementary wires. On the Atlantic Avenue Railway this construction has been abandoned, and a return circuit of four and a half times the conductivity obtained at one-fifth the cost by using No. 0 bonds and no supplementary wires. That is to say, the destructive electric return current has four and a half times the facilities to return in a proper manner provided at one-fifth the cost of the old ineffectual method, and if the improved conductivity is not enough it can be greatly increased at a comparatively small expense, making the total cost less than the method of supplementary wires. In a future issue will be given an abstract of a valuable paper on this subject, going more fully into details.

PART VIII

BIBLIOGRAPHY OF PARTIES CONDUCTING ELECTROLYTIC SURVEYS AND MITIGATIONS

The writer possesses actual personal knowledge as to the subject of "Electrolytic Deterioration" from the diverted electrical currents of grounded electric street railways, from 1893 up to the present date.

In compiling the following list of engineers, whose names will appear on subsequent pages of this report, it was the sincere purpose of the writer to treat all fairly and without prejudice, when making up a brief review of their work on the subject of Electrolysis. The writer will only use facts, as based upon his personal knowledge of such engineers, and also upon their record in connection with this subject, in their respective professional capacities.

FRANK S. SPRAGUE

1. Mr. Frank S. Sprague, through his representatives, unknowingly installed an electrolytic mitigating system in the City of Richmond, Virginia, in February, 1888. This was the date on which the overhead single trolley system first began operating in Richmond.

The real purpose of this apparent electrolytic mitigating system was to enable the electric street cars, to be moved. For the rail-bonding (if there was any at all) was so grossly inefficient, that the return circuit became completely open-circuited, thus leaving the cars without any electric power.

In making the rail-to-water-pipe, metallic connections, an excellent ground circuit was made, and the cars went forth without any further difficulty.

During the few years following (1888) the first electric street car, in the City of Richmond, these rail-pipe connections did serve, in a very crude manner, as an electrolytic mitigating system.

ISAIAH H. FARNHAM

2. Mr. Isaiah H. Farnham, chief engineer, New England Telephone Company, Boston, Massachusetts (1889-94) was undoubtedly

the first engineer in the United States to adopt and install an electrolytic mitigating system. This system was the "Pipe Drainage System" in principle, and he applied it to the lead-sheath covered cables of the New England Telephone Company, in the City of Boston, Mass., in the year of 1892. The electrolytic mitigation was not applied until Mr. Farnham had gone over the electrolytic conditions quite thoroughly and made many experiments and surveys.

In 1893, in Poughkeepsie, New York, Mr. Farnham recommended the "Pipe Drainage System" for the water works system of the City of Poughkeepsie, N. Y., and it was subsequently installed in 1894.

In April, 1894, Mr. Farnham delivered a lecture upon Electrolysis before the American Institute of Electrical Engineers, at Boston, Mass.

This was a very good report, considering that Mr. Farnham had no preceding authorities to which to refer in preparing it.

Mr. Farnham never carried out his plan of electrolytic mitigation further than for protective purposes in connection with the lead-sheath covered cables of the telephone companies.

Furthermore, in this report (1894) Mr. Farnham recommended the experimental use of the "Insulated Rail Return System." Very few engineers would, however, adopt it, and it was not until the year of 1912, that the National Bureau of Standards adopted it in the Mississippi-Ann Substation District of the United Railways Company, St. Louis, Missouri.

Mr. Farnham was assassinated in his office, at Boston, Mass., somewhere about the year 1908. (No definite date could be obtained.)

HAROLD P. BROWN

3. Mr. Harold P. Brown, electrical engineer, New York, N. Y., made a great many electrolytic surveys, especially in those cities close to New York, beginning about the year of 1894. Mr. Brown also assisted Mr. E. E. Brownell, electrical engineer for the City of Dayton, Ohio, in making an exhaustive electrolytic survey, for the Trustees of the Dayton Water Works, in July, 1898.

As he was an engineer of the early days, and an employe of Mr. Thomas A. Edison, made Mr. Brown one of the earliest practical electrical engineers upon this subject.

The litigation against The City Railway Company, Dayton, Ohio, by the City of Dayton, Ohio, followed the above report made by Messrs. Brown and Brownell (July, 1898). It was finally compromised in March, 1911, by E. E. Brownell being made the mutual choice for an indefinite period, to represent both parties and to have certain authorized powers of action.

PROF. DUGALD C. JACKSON

4. Professor Jackson of the University of Wisconsin, late of the Boston School of Technology, Boston, Mass., did the first real experimental laboratory work along this line while in Madison, Wis., in 1894.

Prof. Jackson read a paper (1894) before the "Western Society of Engineers," in which he set forth the chemical and the electrochemical features of this important subject in an excellent manner. No other engineer had, up to that time, ventured into the technic of this subject as far as Prof. Jackson. All of this was laboratory work and highly technical for its day. Much commendation is due Prof. Jackson for this early report, as all the information that could be obtained was needed in those days.

Prof. Jackson was also a witness in the Peoria Water Works Company case, the City of Dayton, Ohio, case and several others requiring technical knowledge of a high degree.

On April 4, 1899, he patented (No. 622,481) the means of making bell and spigot, cast-iron pipe joints of uniform electrical continuity. He undoubtedly had in mind the application of the "Pipe Drainage System" when he took out this patent, as it would have been of no material benefit under any other circumstances.

Notwithstanding the evident purpose of this patent, Prof. Jackson has from the very beginning opposed the introduction of the pipe drainage system, as any part of an electrolytic mitigating system.

In about the year of 1904, he brought legal action against the Peoples Gas Light and Coke Company of Chicago, Illinois, for alleged infringement upon his patent. At this time, E. E. Brownell, electrical engineer, Peoples Gas Light and Coke Company, was putting in a few copper bonds over the lead-calked, cast-iron gas pipe joints for certain specific purposes. The City of Chicago, Illinois, forbade the gas company from running any "Pipe Drainage" cables through its streets, so that to accomplish certain results, the cast-iron, lead-calked gas mains were copper bonded at the pipe joints.

No. 622,481. **Patented Apr. 4, 1899.**

D. C. JACKSON.

MEANS FOR SECURING ELECTRICAL UNITY OF SYSTEMS OF METALLIC PIPES OR MAINS.

(Application filed Oct. 12, 1898.)

(No Model.)

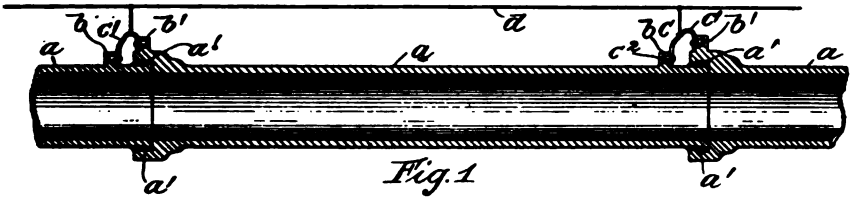


Fig. 1.

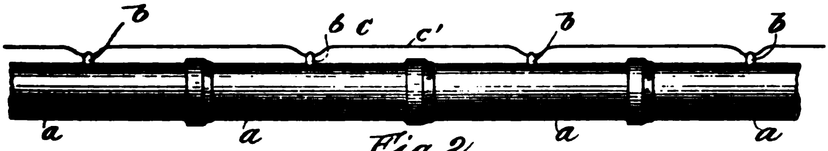


Fig. 2.

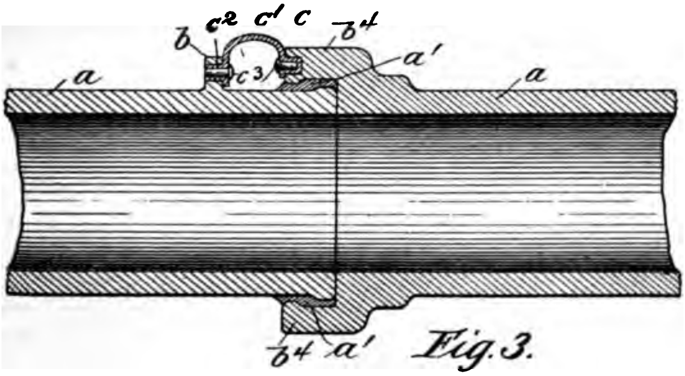


Fig. 3.

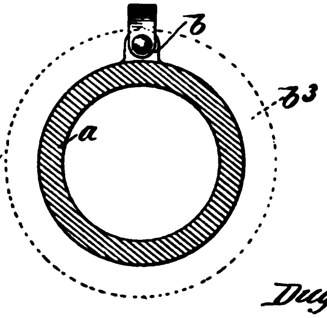


Fig. 4.

Witnesses:

Inventor,
Dugald C. Jackson,
By Barton & Brown,
Attorneys

Professor Jackson's pending litigation was finally settled for a sum of about Five Hundred ($500) Dollars, although he never used or recommended his patent anywhere, nor was it ever used by anybody.

It was, indeed, very strange that he should have patented an appliance, collected money for apparent infringement, and at the same time made dozens of reports condemning the only use for which such an appliance could ever be of any value.

No record can be found where Professor Jackson ever installed, or had installed under his direction, an electrolytic mitigating system. Nor has the writer any personal knowledge of such a case. Professor Jackson's field was of a theoretical nature.

THE UNITED STATES OF AMERICA
UNITED STATES PATENT OFFICE

Dugald C. Jackson, of Madison, Wisconsin

Means for Securing Electrical Unity of Systems of Metallic Pipes or Mains

Specifications forming part of Letters Patent No. 622,481, dated April 4, 1899. Application filed October 12, 1898. Serial No. 693,335. (No model.)

To All Whom it May Concern:

Be it known that I. Dugald C. Jackson, a citizen of the United States, residing at Madison, in the county of Dane and State of Wisconsin, have invented a certain new and useful Improvement in Means for Securing the Electrical Unity of Systems of Metallic Pipes or Mains, (Case No. 2,) of which the following is a full, clear, concise, and exact description.

My invention relates to improvements in means for securing the electrical unity of systems of metallic pipes or mains, the object thereof being the prevention of injury to the same by reason of the disintegrating effect of heavy electrical currents when such pipes or mains afford imperfect conduction for the current.

It has been observed in practice that water mains, for example, become gradually disintegrated when serving in part or entirely as a return-conductor for the current of electric-railway systems.

As is well known, water mains usually are constructed of lengths of cast-iron pipe united at their ends by telescoping the same for a short distance and flowing lead into the annular space separating the said pipes. This connection, while serving satisfactorily to unite the pipes mechanically for their intended use, does not secure the necessary electrical unity between the pipes which is requisite to prevent the disintegrating effect of electric currents.

Having the above considerations in mind, I have devised means for securing the electrical unity of a system of pipes and for preventing injury to the same through the flow of the electric current.

In practicing my invention I form upon the individual lengths of pipe lugs or enlargements which are adapted to receive an electrical bond and unite the several individual lengths to form a continuous conductor. Under some circumstances the said pipes are also connected at intervals with a common conductor especially provided for the purpose of some external conducting body, such as the rails of a street railway system.

I will describe my invention more particularly by reference to the accompanying drawings, illustrating embodiments of my invention as applied to a system of water mains, wherein—

Figure 1 is a longitudinal sectional view illustrating portions of three individual lengths of water pipe having suitable enlargements or lugs provided thereon which are connected by means of electric bonds, the main in addition being connected to an external or supplementary conductor. Fig. 2 illustrates a modification thereof wherein the supplementary conductor or bond is connected to lugs or enlargements formed midway upon the individual lengths of pipe. Fig. 3 is an enlarged longitudinal sectional view of a pipe-joint formed in the manner which I ordinarily prefer in practicing my invention. Fig. 4 is a cross-sectional view of the pipe having a bond attached thereto, the said view indicating also, by means of the dotted line, the provision of an annular enlargement adapted to receive the bond at any portion of its circumference.

The same letter of reference is used to designate like parts in each of the several figures of the drawings.

The individual lengths of pipe a are united in the well-known manner by means of molten lead a', flowed between the pipe ends and compacted by cold-chiseling. Upon the individual lengths of pipe are provided lugs or enlargements b, and in the form shown in Figs. 1 and 3 additional lugs or enlargements b' are provided upon the lengths of pipe, between which lugs extend the conductors or bonds c.

In Fig. 4, showing the transverse sectional view of the bonded pipe, the lug or enlargement is indicated as taking the form of an annular enlargement or ring b^3, which obviously is the full equivalent of the form shown in the other figures with the additional advantage that connection may be effected at any point upon the circumference of the pipe. This advantage is shared as well by the employment of an enlarged flanged coupling-head b^4. (Shown in Fig. 3.)

I may employ any suitable form of bond, but will describe the one preferred by me, which consists of a conductor c', provided at its ends with tubular extensions c^2, which are adapted to fit within holes bored in the lugs or enlargements provided upon the abutting ends or other portions of the pipe and are then expanded by means of the slightly tapered cylindrical plugs c^3, which are driven into the openings provided in said extensions, and the heads thereof are riveted or battered down to form a close joint between the bond and the lengths of pipe. This serves to secure the electrical unity of the lengths thus united.

In Fig. 1 the bonds c serve to connect lugs b b', formed upon the abutting ends of the lengths of pipe, the said bonds being in turn connected with an external conductor d, which may be laid alongside the mains or otherwise suitably disposed for this special purpose, or it may consist, instead, of any suitable external conductor, such as the rails of an electric railway system.

In Fig. 2, which is best adapted for uniting the lengths of pipe under some circumstances, the bond takes the form of a conductor c', extending throughout the length of the main or pipe, and is electrically united with the individual lengths of pipe by means of lugs formed midway upon the same.

Except in the event of using very heavy mains having thick walls it is undesirable to drill directly into the body of the wall or main and in any position where the same would be weakened, and I have theretofore deemed it expedient to show water mains wherein enlargements of suitable form were provided thereon, serving, when connected by suitable bonds, to unite the pipes electrically, while in no wise weakening the mains for their intended use.

It will be seen that water mains or other systems of piping when united in the manner indicated above will be free from any injurious effects commonly resultant from the flow of heavy currents throughout the length of pipe.

It is apparent that numerous alterations may be made in the precise means shown for practicing my invention without departing from the spirit thereof, and I do not desire to be understood as limiting my said invention to the exact embodiment herein shown and described; but,

Having set forth the preferred means for practicing my invention, what I claim as new, and desire to secure by these Letters Patent, is—

1. As a new article of manufacture, a length or section of fluid-conducting pipe or main having an enlarged portion formed thereon adapted to be connected with an electrical conductor, whereby an effective electrical joint may be obtained between said section or length and an adjoining section or sections, and the main is preserved from deterioration, substantially as described.

2. As a new article of manufacture, a length or section of fluid-conducting pipe or main having enlarged portions formed thereon at or near either end adapted to be connected with electrical bonds or conductors united with adjoining lengths of fluid-conducting pipe, whereby the electrical unity of the system formed of said pipes is secured, substantially as described.

3. A system of fluid-conducting mains consisting of individual lengths of pipe mechanically united to form a continuous pipe or main, said lengths of pipe being provided with enlarged portions, and electrical conductors or bonds connected between the enlarged portions of the pipe or main, whereby the electrical unity of the system is secured, substantially as described.

4. The combination with a plurality of individual lengths of pipe, a, having enlarged portions b provided thereon, said lengths of pipe being united to form a continuous fluid-conducting main, of electrical bonds or conductors, c, connected with the said enlarged portions b, whereby the lengths of pipe are electrically united, thus securing the electrical unity of the system of pipes or mains, substantially as described

5. The combination with a plurality of lengths or sections of pipe united to form a continuous main and having enlarged portions provided at or near the ends of said sections, of electrical bonds c connected between the said enlarged portions, whereby the electrical unity of the main is secured and deterioration is obviated, substantially as described.

6. The combination with abutting lengths of a water main a mechanically united to form a single fluid-conducting main, of lugs b b' formed at or near the ends of said lengths, the same being drilled to receive electrical bonds, and bonds c connected between the said lugs b b' adapted to secure the electrical unity of the system, whereby the injurious effects of heavy electric currents are avoided, substantially as described.

7. The combination with a plurality of sections or lengths of fluid-conducting pipe a united to form a continuous main and having enlarged portions b, of electrical bands c connected between the said enlarged portions, and a supplementary conductor d electrically connected at intervals with the main, whereby the electrical unity of the same is secured, substantially as described.

In witness whereof I hereunto subscribe my name this 13th day of August, A. D. 1898.

DUGALD C. JACKSON.

Witnesses: Lizzie Armstrong,
Mabel F. Jackson.

GEORGE W. PLYMTON AND FRED R. LEE,

Commissioners of Electrical Subways, Brooklyn, New York

5. Reports made by Mr. Plymton and Mr. Lee, dated February 27, 1894, and addressed to Hon. Charles A. Schieren, Mayor of Brooklyn, New York, and supplemnted by another report on December 15, 1893, were very good articles for those days. No electrolytic mitigation followed these reports, but great destruction from this cause came to light in Brooklyn in after years.

THOMAS J. McTIGHE

6. In the Spring of 1894, Mr. McTighe of New York, N. Y., read a very exhaustive report upon the subject of electrolytic corrosion, before the Street Railway Association of New York City. Mr. McTighe was then chief engineer of the Atlantic Avenue Railroad Company of Brooklyn, New York. It is of more than ordinary importance to know that the electric street railway companies had a representative who could grasp a comprehensive view of this matter, even though it was in 1894.

J. H. VAIL, M. E. E.

7. On and between February 27 and March 1, 1894, Mr. J. H. Vail, Member of the American Institute of Electrical Engineers, delivered an exhaustive lecture on Electrolysis before the Annual Electric Light Association Convention in Washington, D. C.

This report is an excellent one, and is well worth reading by any interested party.

Mr. Vail, though technically well versed, arrived at many of his conclusions through a common knowledge of the subject matter rather than through any actual personal field work.

JOHN M. GOODELL

8. On November 21, 1893, Mr. John M. Goodell, Worcester, Mass., sent a written communication to the editor of "Engineering," and gave very clearly a brief review of electrolytic conditions up to that date. Nothing further is known of Mr. Goodell on this subject.

F. S. PEARSON,

Chief Engineer of the West End Street Railway Company of Boston

9. At the annual meeting of The American Street Railway Association, held in Cleveland, Ohio, in the Fall of 1892, the electric railway companies had the opportunity of learning, first hand of the electrolytic conditions in the City of Boston, Mass. This was about the first discussion of this subject ever entered into at a street railway convention in the United States, and occurred about 30 months after the first electric street car in the City of Milwaukee began to run.

STUART SMITH

10. On April 13, 1895, Mr. Smith concluded a very valuable review of the whole subject of electrolysis. This review was published in "The Electrical World" in a series of articles. Mr. Smith had a very good idea of this subject, and especially of its practical features.

PHILIP DAWSON

11. On February 15, 1895, Mr. Dawson further reviewed this subject up to that day. A complete copy can be seen in "Engineering"

of that date. Nothing more seems to have been done by Mr. Dawson.

ARTHUR V. ABBOTT

12. Mr. Abbott's writings are of more than ordinary interest. In the "Western Electrician" of August 31, 1895, he takes up the question of investigations being made by others, who proposed using the "Three-wire System" as an electrolytic mitigating system. In his report he condemns the the three-wire system. (This installation is now (1919) being tried in the North Avenue Substation District of The Milwaukee Electric Railway and Light Company.—E. E. B.)

JAMES RALEY

13. In June, 1893, Mr. Raley made a brief resume of the Boston, Mass., electrolytic conditions, with various comments.

ALBERT B. HERRICK

14. Albert B. Herrick, electrical engineer, New York, N. Y., who made many electrolytic surveys and did much research work, covering many years, especially from 1895 to 1912, was one of the most practical of the electrical engineers of the early school. Mr. Herrick invariably took the side of the electric street railway company in this controversy, never appearing to give the subject the real importance that it deserved.

So far as the writer has ever been able to learn, Mr. Herrick never installed an electrolytic mitigating system of any moment. He would recommend improving the electrical conductivity of the rail-return circuit, by good rail bonding and supplementary track feeders, and then consider it unnecessary to go beyond a tolerably high track gradient loss. Many of the litigations of years ago were largely due to Mr. Herrick's recommendations not to co-operate with pipe-owning interests. It appeared many times, as though he would rather litigate than mitigate.

He was the chief witness for The City Railway Company, in the City of Dayton, Ohio, litigation of 1899 to 1911. During the last few years Mr. Herrick has discontinued this line of work.

A. A. KNUDSON

15. Mr. A. A. Knudson, electrical engineer, New York, N. Y.,

(now deceased) made a large number of electrolytic surveys on gas, water and other subsurface metallic structures, beginning 1895 and ending about 1910. He invariably represented those interests that were opposed to the electric street railway companies. Mr. Knudson possibly conducted more electrolytic surveys, during his day, than any other one engineer in America, the writer excepted. However, he never installed an electrolytic mitigating system, so far as the knowledge of the writer extends, nor can any records to that effect be found. In the early experimental work of electrolytic action upon reinforced concrete construction, Mr. Knudson was undoubtedly the pioneer in this special research field.

DABNEY H. MAURY

16. Mr. Dabney H. Maury, consulting engineer, Chicago, Illinois, made many extensive electrolytic surveys throughout the Middle West, from about 1894 to 1912. Since then Mr. Maury has done little or no work along this special line of investigation.

Mr. Maury always took, on general principles, the plaintiff's side of this question, in a vain attempt to get the courts to compel the electric street railway companies to adopt the "Double Trolley System."

Shortly after the failure, in the Dayton, Ohio, case, to get a court decision of this character, Mr. Maury ceased to further take up this work.

Much credit is due Mr. Maury for the manner in which he conducted the Peoria, Illinois, case, in behalf of the Peoria Water Works Company, even though the principle for which he contended was not good engineering and apparently wrong. This suit was filed March 21, 1898, and a drawn decision rendered on May 13, 1912. Mr. Maury left the service of the Peoria Water Works Company about this time, so that nothing has been done in this co-operative decision of Judge A. L. Sanborn, of the United States District Court for Northern District of Illinois, Eastern Division, No. 24,193 case, since May 13, 1912.

It is to be regretted that Mr. Maury's principles could not have seen their way clear to continue this case to a final legal conclusion, after expending a fortune during the many legal steps taken from 1898 to 1912, or fourteen years of litigation.

PROF. GEORGE F. SEVER

17. Prof. George F. Sever, Columbia College, New York, N. Y., has given a great amount of theoretical and technical consideration to this subject. His experience began prior to the Dayton, Ohio, case, where he was one of the principal witnesses for the defendant; in fact, he always took the position of defending the electric street railway companies.

Professor Sever never installed an electrolytic mitigating system, but he did a little work in Trenton, New Jersey, for the Trenton and Mercer County Traction Company, and in Delaware County, Pennsylvania, for the Philadelphia and West Chester Traction Company. In both of these cases, his plan consisted of increasing the electrical conductivity of the rail-return circuit to a fairly reasonable state of efficiency.

As a technical engineer of the highest type, Professor Sever was better qualified to act in a professional capacity where theoretical matters were involved, than as a practicing electrical engineer.

He has done some splendid work on electrolytic compilations of the work done by other consulting electrical engineers.

DR. CARL HERING

18. Dr. Carl Hering, consulting electrical engineer, Philadelphia, Penna., is unquestionably the most skilled consulting electrical engineer, in the United States, when it comes to taking any kind or character of electrical measurements for analytical purposes. His many years of research work have proven his requisite qualifications to the satisfaction of those who are best able to judge.

Dr. Hering has never been engaged in the installation of an electrolytic mitigating system.

OTHER ENGINEERS WITH ELECTROLYTIC EXPERIENCE

19. The engineers whose names appear below, have given considerable thought and study to the electrolytic action upon subsurface metallic structures. These are:

Messrs. Adams, Barrett, Davis, Gray, Hewitt, Hoopes, Jenkins, Low, Morse, Newbaker, Perry, Rowland, Dr. Samuel Sheldon, Schoen, Storrs, Swinburne, Whynkop, A. E. Kennelly and many others.

STONE AND WEBSTER, ENGINEERS

20. On January 31, 1894, Messrs. Stone and Webster, engineer of Boston, Mass., made a report to William Jackson, City Enginee upon the electrolytic conditions in the City of Boston, Mass., wi respect to the electric street railway current diversion from the sy tem of the West End Street Railway Company.

(See their report in Chapter VI of this report.)

In August, 1896, they also made a written report to the Electric Bureau of the "National Board of Fire Underwriters." Since th (1896), practically all of their investigations and reports have be of a confidential nature; although they were in an enviable positic during all these years, to have rendered an exceedingly valuable se vice upon the engineering features of this important subject.

PROF. ALBERT F. GANTZ

21. No engineer who has ever taken up the subject of Ele trolysis, has occupied a position so much in the limelight, as did Pr fessor Gantz (deceased July 29, 1917), late Professor of Electric Engineering, Stevens Institute, Hoboken, New Jersey.

Professor Gantz did a great amount of actual research wor in the field as well as in the laboratory.

He was the official spokesman for the American Gas Institu and for gas interests in general, from about the year 1904 until h tragic death.

Strange to say, he took a similar view to that invariably take by Mr. Maury; that is, that the Double Trolley was the only real sol tion to this menacing evil. When the National Bureau of Standard entered the field in 1911, Professor Gantz became associated with in St. Louis, Mo., Springfield, Ohio, and Springfield, Mass., install tions of the Insulated Rail Return System of electrolytic mitigatio

From the year 1912, Professor Gantz became a warm advoca of the Insulated Rail Return System, as the best protective measu to adopt against the ravages of electrolytic deterioration or corrosio

In the City of Canton, Ohio, in 1915, he had The Northern Oh Light and Traction Company string a 500,000 c. m. aerial copp cable from its powerhouse, negative busbar, to the central portion the City of Canton, Ohio, about one (1) mile distant, as a suppleme tary rail return feeder to the tracks. So far as the writer can learn, this is the extent of Prof. Gantz' actual field work on electrolytic mitigation, except where associated with the National Bureau of Standards. Prof. Gantz was a very bitter enemy to the "Pipe Drainage System" in any form whatsoever. (See page 7 of the Springfield, Ohio, report of the National Bureau of Standards, dated February 11, 1914, for confirmation.)

Professor Gantz always failed to see that there were other important sides to this question, and, the writer is sorry to say, he showed a marked tendency toward becoming very egotistical on matters of this nature, which probably was largely because of his rapid rise in the theoretical technical world.

Had Professor Gantz been less radical, he might have been of unlimited service to both sides of this controversy, by making equitable adjustments between the dissenting parties. If one's opinion agreed with his views, one was an engineer; otherwise not.

RAY PALMER

22. Mr. Ray Palmer, New York, N. Y., former City Electrician of Chicago, Illinois, began his first actual field experience upon the subject of Electrolysis with the writer. This was in the year 1901.

At that time Mr. Palmer was electrical engineer for the Chicago Union Traction Company, under John Z. Murphy, Chief Engineer, and the writer was Consulting Electrical Engineer for the Peoples Gas Light and Coke Company, of Chicago, Ills.

Mr. Palmer has, for many years, had the opportunity of studying electrolytic conditions in the largest single trolley system city in the world, with all of its numerous complicated ramifications.

His many surveys and practical experiences, in the City of Chicago, especially on various electrolytic mitigating plans, gave him an excellent practical knowledge, and made him very well versed upon the subject.

Mr. Palmer's Electrolytic report, dated September 30, 1911, and made to the City of Milwaukee, Wisconsin, under the auspices of the "Bureau of Economy and Efficiency," giving electrolytic conditions in the City of Milwaukee, was a very plain, common sense, thorough report.

Mr. Palmer's report (1911) is herewith printed by the writer and made a part of this report. Mr. Palmer recommends the "Pipe Drair age System" of electrolytic mitigation, after proper repairs had bee made in the rail-return circuits of the Milwaukee street railway His practical experience, on electrolytic mitigation, was limited t the City of Chicago, so far as the writer has ever known.

CLARENCE R. PIERCE

26. Mr. Clarence R. Pierce, Chicago, Illinois, also obtained h initial training and practical experience under the direction of tl writer, in the City of Chicago, Ills., beginning in the year of 190 For several years, he filled the position resigned by the writer, wi the Peoples Gas Light and Coke Company. He then became ident fied with the staff of the Board of Supervising Engineers for the Ci of Chicago, Ills., on electrolytic matters for many years. Mr. Pier has had even a better opportunity than Mr. Palmer to make a car ful, practical study of this problem. He did actual electrolytic mi gation installation work in a great city where extremely heavy r turn circuits had to be handled.

The writer does not remember that Mr. Pierce ever installed a electrolytic mitigating system outside of the City of Chicago; althoug he made electrolytic surveys elsewhere.

Mr. Pierce's report, dated September 29, 1910, and made to tl Wisconsin Railroad Commission, on electrolytic conditions in tl City of Milwaukee, is very well treated and does not confuse the re issue by bringing in a mountain of irrelevant theoretical hypothese

(The writer has printed this report (1910) and made it a part o this report.)

PROF. C. F. BURGESS

24. Prof. C. F. Burgess, Madison, Wisconsin, took the position as the professional advisor, made vacant by the writer's resignation with the Peoples Gas Light and Coke Company, in the City of Chi cago, Ills., in 1905. This was his first actual entrance into the fiel of electrolysis work.

Professor Burgess has always been opposed to the installatio of the Pipe Drainage System. He was the means of persuading th Peoples Gas Light and Coke Company not to install any further elec trolytic mitigations with this system. This continued refusal alway prevented any amicable arrangements being successfully worked o in the city of Chicago, Ills., as between the gas company and the various electric street railway companies, up to the time of his resignation from the gas company.

Like most theorists, Professor Burgess never believed in the co-operation necessary to the proper solution of this problem. No improvement in the electrolytic situation in the City of Chicago was made during his many years of professional connection with the gas company.

The street railway companies of the City of Chicago, Ills., have always maintained that they were helpless to correct menacing electrolytic conditions, upon the subsurface metallic structures without the full approval and practical support of the City and the pipe companies.

The joint report of C. R. Pierce, W. B. Schulte and Prof. C. F. Burgess, dated August 20-29, 1912, and signed September 6, 1912, which was made for the Wisconsin Railroad Commission, on electrolytic conditions in the City of Milwaukee, Wis., is a short description of the electrolytic conditions of 1912. It condemns the manner in which The Milwaukee Electric Railway and Light Company, without municipal authority, has installed the Pipe Drainage System on the Milwaukee Water Works.

This report is also printed by the writer and made a part of this report.

Professor Burgess was not an associate in the famous Rosa-Jackson-Warren report, dated December 21, 1912, as made by these gentlemen for the Peoples Gas Light and Coke Company of Chicago, Ills.

So far as the writer has ever been able to learn, Professor Burgess never installed an electrolytic mitigating system, but he has in several instances acted as advisory engineer for the Wisconsin Railroad Commission in considering this subject. Beloit, Wisconsin, is said to have been the only place where Professor Burgess' recommendations were carried out by the Wisconsin Railroad Commission.

EDWIN A. FISHER

25. Mr. Edwin A. Fisher, city engineer, Rochester, New York, was also very well posted upon the practical side of electrolytic surveys and mitigations. His 82-page report, dated August 1, 1901, and

made to the Commissioner of Public Works, Mr. J. Herbert Grant, was the most complete municipal compilation ever made up to that time, upon the subject of electrolysis. Mr. J. E. Putnam, electrical engineer and assistant to Mr. Fisher, did considerable field work in and around Rochester, New York, many years ago. The City of Rochester plainly showed the results of these gentlemen's efforts, so far as electrolytic action was concerned.

FRANK N. WATERMAN

26. Mr. Frank N. Waterman, consulting engineer, New York, N. Y., has for some years appeared as the author of many articles upon this subject. Mr. Waterman was associated with Professor Gantz in the verification report on the installation of the Insulated Rail Return System, in the Mississippi-Ann Substation District of the United Railways Company of St. Louis, Mo., in May, 1914, as made by the National Bureau of Standards.

No record can be found where Mr. Waterman ever installed an electrolytic mitigating system, directly or indirectly.

SAMUEL S. WYER

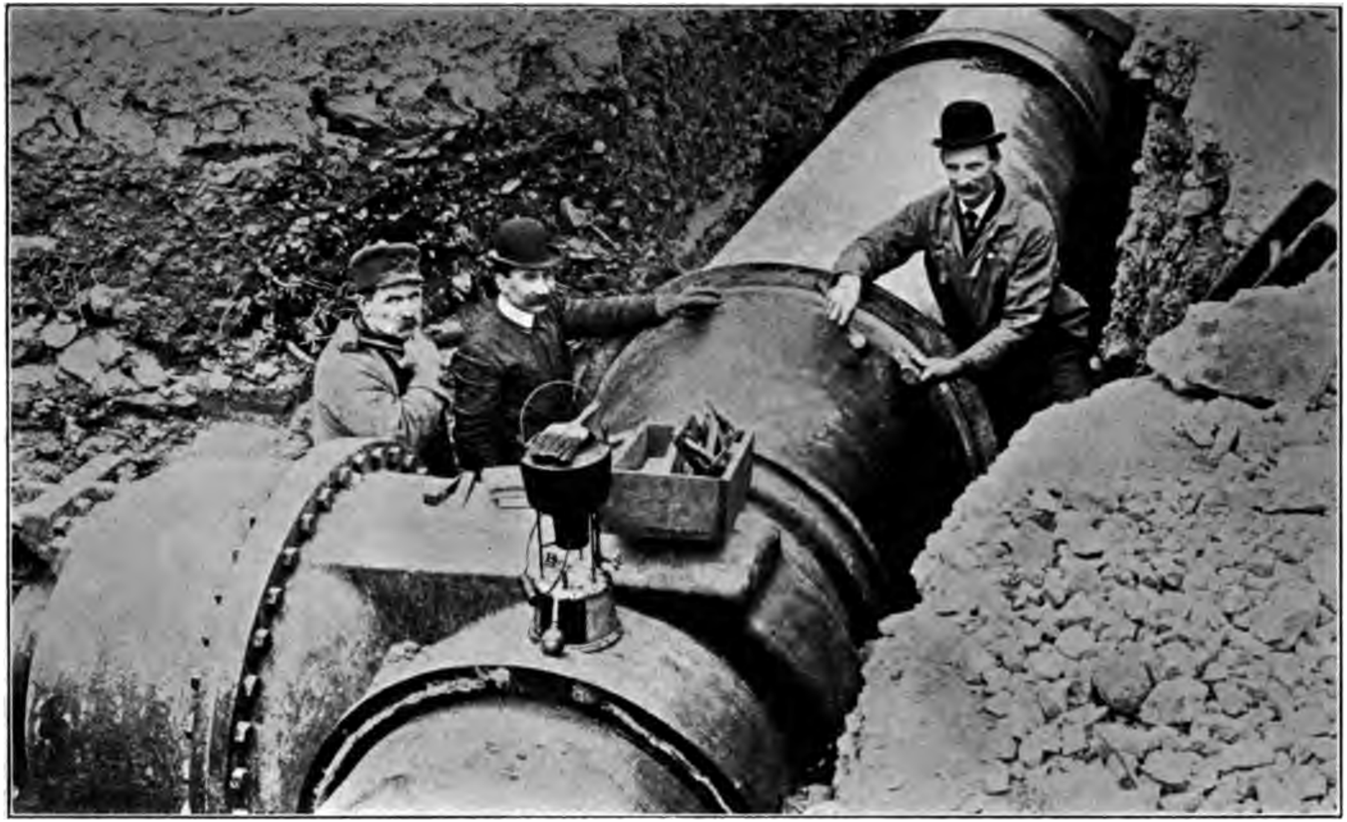
27. Mr. Samuel S. Wyer, consulting engineer, Columbus, Ohio, has written several extensive articles upon electrolytic conditions and the mitigation of them. These are all theoretical, as the present writer has no knowledge, nor is there any record, of Mr. Wyer ever supervising the installation of an electrolytic mitigating system of his own. He has also conducted but few electrolytic surveys, and all of these seem to be upon gas piping systems.

Mr. Wyer was associated with Professor Albert F. Gantz, Frank N. Waterman, Howard S. Warren and Elam Miller, on the joint ratification report, made in May, 1914, supporting the technical position of the National Bureau of Standards, as to the efficiency of the Insulated Rail Return System, which was installed by the United Railways Company in the City of St. Louis, Mo.

Mr. Wyer has invariably sided with the gas companies on this question for some years past, or as long as he has been interested in this subject.

HOWARD S. WARREN AND ELAM MILLER

28. Mr. Warren and Mr. Miller are both identified with the



MAKING WOODEN INSULATING JOINTS ON 48-INCH CAST IRON WATER MAIN IN BROOKLINE, MASS., 1909

American Telephone and Telegraph Company, the parent company of the Bell Telephone Companies.

While these gentlemen may be very well versed upon electrolytic surveying and mitigating upon their own lead-sheath covered cables, they have never done any such work outside of their own field, except to assist in the compilation of the joint Rosa-Jackson-Warren report to the Peoples Gas Light and Coke Company, dated December 21, 1912, the verification report of St. Louis, Mo., dated May, 1914, and the Springfield, Ohio, report of February 11, 1914. All of which have been in connection with the work done under the auspices of the National Bureau of Standards.

As these gentlemen represent a great octopus public service corporation, it is only natural that they should use methods which are not in line with good professional ethics. This applies even more forcibly to their local representatives than to them.

It is the same old defeated principle of 1888-1894, that "We own the exclusive use of the earth," the rights of others being always subservient to the interests of the telephone companies.

W. E. FOSS

29. Mr. W. E. Foss, consulting engineer, Metropolitan Water Board, Boston, Massachusetts, has made many electrolytic surveys in and around the city of Boston, beginning about the year of 1896. It was Mr. Foss, as technical advisor, who recommended to the Metropolitan Water Board the installation of wooden pipe sections inserted periodically, in large lead-calked, cast-iron water mains, in an attempt to prevent acute electrolytic action upon the cast-iron pipes.

(See photograph in this report showing installation in Brookline, Mass.)

This is the first instance where such an installation was made to lessen acute electrolytic corrosion, or as an electrolytic mitigating measure. The protective electrolytic features of this installation are very much doubted by the writer. It appears to be a very impractical method.

E. E. LANPHER

30. Mr. E. E. Lanpher, engineer, Pittsburgh Bureau of Water, Pittsburgh, Pennsylvania, has been in very close touch with all the

practical work done in the City of Pittsburgh. Being a highly technical scholar of the day, Mr. Lanpher possesses the requisite practical and theoretical knowledge of this subject. His work has covered the municipal engineer's viewpoint upon this subject very clearly. From 1905 to 1919, or a period of 14 years, he has been concerned with and has known of many interesting features of this matter.

It was Mr. E. E. Lanpher and the writer who protested so vigorously against the installation of an electrolytic mitigating system, in the City of Pittsburgh, Penna., (1906) without a written, legally authorized contract between the City of Pittsburgh and the Pittsburgh Railways Company. A good lesson for the City of Milwaukee at the present time.

OSCAR CLAUSSEN

31. Mr. Oscar Claussen, City Engineer, Saint Paul, Minnesota, with A. J. Stobbart, assistant corporation attorney, and Mr. John C. Caulfield, secretary of the Board of Water Commissioners of St. Paul, Minn., compiled a very interesting 66-page printed report, dated November 9, 1901, on electrolytic conditions, in the City of St. Paul, Minn. It was an unusually well written report upon local electrolytic conditions, with the various phases of the subject carefully treated. This report followed the Rochester, N. Y., municipal report by about three months. It did not give quite as extensive a review of the subject as applied throughout the United States, as did the latter, but it gave a better local resume.

GEORGE H. BENZENBERG

32. Mr. George H. Benzenberg, consulting engineer, Milwaukee, Wisconsin, stands alone as the engineer who has seen more earlier important and practical phases of the subject of Electrolysis, than any other municipal officer or engineer in the United States. He has lived with the subject and viewed it from almost every angle that can be conceived of, from about 1891 until the present time.

On April 29, 1893, it was Mr. Benzenberg who called the attention of the technical fraternities to this vital issue, after the 6-inch c. i. water main was completely electrolized on Wells Street, Milwaukee, and broke on the above date.

Until this time, it was thought that cast-iron was immune to the effects of electrolytic corrosion from electric street railway diverted currents; but Mr. Benzenberg proved the contrary with actual indisputable facts on the subject in 1893.

It was Mr. Benzenberg who formed the "Electrolysis Committee" of the American Water Works Association, in 1894, and who acted for many years as its chairman. This misguided committee was finally dissolved, after about 20 years' existence, by others who knew far less than Mr. Benzenberg, its chairman.

The practical inactivity of the American Water Works Association, in failing to get concrete results, is undoubtedly due to the policy of Dabney H. Maury, technical electrolysis advisor at large for the Committee and the Association. With Mr. Maury's double trolley theory, nothing but litigation would have brought the necessary results, and as the legal outlook was not very bright on the famous Peoria Water Works Company's case from 1898 to 1912, the members of the Water Works Association merely sat and waited, but of no avail.

Mr. Benzenberg readily saw this, but the majority usually rules and thus the matter drifted along without results.

The original Electrolysis Committee was George H. Benzenberg, Chairman; E. Mather, Harrisburg, Penna.; F. A. W. Davis, of Indianapolis, Ind., and L. H. Gardner, of New Orleans, La.

DR. GELLERT ALLEMAN

33. Dr. Gellert Alleman, Professor of Chemistry, Swarthmore College, Swarthmore, Penna., possesses a greater knowledge and experience of the electro-chemical features of this subject than any professional man, or aggregation of men.

His many years of laboratory and field research, both in America and abroad, have given him this unexcelled knowledge of the subject.

Dr. Alleman has established new technical chemical laws, as applicable to electrolytic deterioration from every conceivable angle; also the rate of electrolytic depreciation, and under what conditions these laws apply. He has established the identity of electrolytic action, upon subsurface metallic structures, as against ordinary chemical action of the soils, and has shown how to prove it.

Dr. Alleman is not a theorist, but a genius with unlimited technical training which has been the means of producing marvelous conclusions.

This information has not, as yet, been made public on accou of ethical reservations due to his clients. His financial supporte have been able to provide sufficient funds to keep this extremely i portant line of research going on uninterruptedly for a great ma years.

NOTE: It has always seemed strange to the writer that t National Bureau of Standards laboratory, at Washington, D. under the direct supervision of the Government of the United Sta of America, with all of its presumably highly skilled talent, shou have failed to bring to the attention of the interested public, the r and most fascinating laboratory aspects of the electro-chemical si of this subject.—E. E. B.

In all of the various and numerous technological reports, ma by the National Bureau of Standards, they have yet to even menti the vital electro-chemical part of this important subject.

This is where the representatives of the National Bureau Standards should, by virtue of its presumed talent and unlimit appropriations from Congress (a vast sum annually), surpass t efforts of all other professional and private talent.

The country would be far better served, if the National Bure of Standards would confine its efforts to the lines originally intende and not make any attempt to do operative or constructional pub utility engineering work. Attempting to be consulting engineers the expense of the taxpayers of the United States is decidedly wro in principle.

ELECTRIC STREET RAILWAY ENGINEERS

On the electric street railway side of the question of Electrolysi there are many electrical engineers who are exceedingly well-verse from practical experience, upon this subject.

They have opportunities to obtain data and other information o their own. This soon brings them to some definite conclusion as t the best ways and means of handling this subject matter.

It is quite common to find these well-posted men, who see littl of the theoretical side of this matter, but who know its practic features far better than any representative of the National Burea of Standards have ever for the last ten years given evidence of know ing. This is true of Mr. John Z. Murphy, electrical engineer, Ch cago Railways Company; Mr. Herbert S. Murphy, electrical enginee

Philadelphia Rapid Transit Company; Mr. E. J. Blair, electrical engineer, Chicago Elevated Railways Company, and especially was it true with respect to the late W. M. Wheeler, of the Chicago Railways Company.

Mr. Bion J. Arnold, chairman, Board of Supervising Engineers of Chicago, Ills.; Mr. Arthur S. Richey, of Worcester, Mass., 1913 chairman of the Electrolysis Committee of the American Electric Railway Association; Martin L. Schrieber of the Public Service Railway Company; these together with several others, have all occupied executive positions which have made them generally learned upon the subject.

Mr. C. P. Steinmetz of the General Electric Company, can undoubtedly be relied upon as the highest technical authority, upon this subject, from the electrical street railway companies' point of view. His statement made in 1907, before the American Institute of Electrical Engineers, proves this without any doubt. Mr. Steinmetz is a wonderful genius. He recommends the Pipe Drainage System as the best means for electrolytic mitigation.

BRIEF COMMENTS BY THE WRITER ON THE PRACTICAL PROFESSIONAL ENGINEERING FEATURES

The following brief conclusions are drawn by the writer from the records of the foregoing engineers, namely:

1. So far as technical talent, past and present, is concerned, the various engineers, including representatives from the National Bureau of Standards, are well able to conduct electrolytic surveys. There is an abundance of talent.

2. A far lesser number of engineers, however, are possessed of sufficient practical learning on the subject, to install the proper electrolytic mitigation.

3. Therefore, taking into consideration the experience of the above named engineers, together with that of others not mentioned, representative of the National Bureau of Standards, and any individuals who had any practical or theoretical experience upon the subject and the conclusion in the following paragraph must inevitably be drawn.

4. **Their records will show without fear, favor or prejudice, that in not one single instance, has any one of these gentlemen, for whom**

in most instances the writer has the highest professional respect, ever brought this subject, as a whole, to a proper completion.

5. In other words, they never negotiated an amicable contract between contending parties, installed an electrolytic mitigating system, and placed the subject matter upon a practical, legal, efficient and thoroughly business-like basis by which both sides would receive full equitable relief and know just what to depend upon thereafter.

This is the greatest objection to the methods of the National Bureau of Standards, as well as others engaging in this professional engineering work. They all lack something that is necessary to make the work complete. The organization they effect is either bad, or without due process of law; incomplete or with verbal understandings only, and nothing specifically agreed upon; loose ends galore, all technical and nothing practical; with no provision for the future, divided operative responsibility and many other serious defects. Any one of which faults is sufficient to make the work of electrolytic mitigation installation a decided failure.

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Barrett	Brooklyn, N. Y.	Jan. 18, 1895	Railroad Gazette	Report to commissioners of electric subway
"	" "	Jan. 26, 1895	Street Railway Gazette	Report to commissioners of electric subway
"	" "	Feb. 23, 1895	Engineering Record	Report to commissioners of electric subway
Bridgden	Battle Creek	April 15, 1900	Engineering Record	Injury—Map
"	" "	Vol. 8, No. 6, 613	Cassier's	Protecting pipes
"	" "	Vol. 5, No. 12, 739	Street Railway Review	Potential readings
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"	" "	Oct. 14, 1897	Electrical Engineer	Amer. and European practice
"	" "	March, 1899	Domestic Engineer	Testing and protection
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"		April, 1895	Cassier's	Legal aspect
"		April 6, 1895	Street Railway Gazette	Legal aspect
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Chamen	Glasgow, Scotland	June 7, 1898	Journal Gas Light	Report
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Davis	American Cities	December, 1899	Municipal Engineer	Conditions in cen. state
Dayton	Dayton			Trial—Evidence
Expert Engineer	St. John, N. B	Jan. 4, 1894	Engineering News	Pipe breakage
" "	" "	March 29, 1894	" "	Broken returns
" "	" "	Jan. 26, 1899	" "	Abstracts of report
" "	Jersey City	Feb. 2, 1899	" "	Abstract Knudson's report
" "	Cambridge, Mass.	Oct. 14, 1893	Engineering Record	Increased bonding

AUTHORS AND PUBLICATIONS ON ELECTROLYSIS—Continued

Investigator	Locality	Date	Publication	Remarks
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"		April 25, 1894	Electrical Engineer	" "
"		May 3, 1894, etc.	Engineering News	Corrosion of pipes conclusively shown
"		May 11, 1894	Railroad Gazette	Corrosion of pipes conclusively shown
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BOSTON, MASSACHUSETTS

ELECTROLYSIS OF WATER PIPES

By Charles A. Stone and Howard C. Forbes (New England Water Works Association)

June 14, 1894

THE DESTRUCTIVE ACTION OF ELECTRIC CURRENTS ON WATER PIPES.

History: The effect of electrolytic action in corroding water and gas pipes in cities where electric railways have been adopted, is a subject which is now attracting a good deal of attention. It is impossible as yet to determine the extent of the injury resulting from this cause, but sufficient evidence is at hand to show that it is a matter worthy of most careful consideration.

Up to the time that single trolley systems of electric railways were generally adopted, no considerable amount of electricity flowed through the earth, except such as might leak away from the accidental grounding of electric lighting wires. With the first introduction of electric roads, the rails were adopted as a path for conveying the current from the cars back to the power station, and it was soon found that the joints, even when thoroughly bonded, had so great a resistance that a portion of the current flowed from the rails into the earth. In many cases, it was found that the conductivity of the circuit as a whole, could be materially increased by connecting the rails at various points with the moist earth, allowing the current to seek its own way from there to the power station. Until recently most electrical engineers have supposed the body of the earth to be so good a conductor, that the quantity of electricity which could pass through it safely was practically unlimited. Recent investigation, however, has shown that the earth is in reality very unreliable as a conductor; and that only under certain favorable conditions, is its resistance such as to permit the passage of currents of any considerable magnitude.

This fact was brought to the attention of the public about two years ago, when it was discovered that in certain places in Boston,—and in other cities where electric roads had been adopted,—differences of potential existed between adjacent pipes. It was found in one place that a steam pipe and a water pipe in the same building, not more than twelve inches a part, had a difference of pressure between them, of about eight volts; and that upon connecting the two with a stout piece of wire, a sufficient current flowed, to bring the wire to a white heat. In one or two instances advantage was taken of their conditions and small motors were driven from this source of power. Such a state of affairs was considered extremely dangerous from a fire point of view, and accordingly the subject was investigated by the electrical inspectors of the Boston Board of Fire Underwriters and others.

EVIDENCE THAT ACTION IS OCCURRING.

The action of electrolysis is to corrode the pipes at the point where the current leaves them. This corrosion as we shall show, is not uniformly distributed over the surface, but is quite irregular, usually producing deep pits. The result is therefore an acceleration of the natural decay of the pipes,—the rate of corrosion increasing as the current flowing out of the pipe becomes greater.

Evidence of injury to water and gas pipes by electric action, would therefore naturally be expected to take two forms ; one the premature giving out of the pipes, the other, an increased rate of renewals and repairs.

Evidence of the former sort would presumably be the first to develop itself, and there are already many examples of this action, which it will be interesting to consider.

But in this connection we must guard against one point which might lead us astray. So much attention has been given of late to electrolytic action, that the premature decay of pipes from any cause, is likely to be attributed to electricity.

Now the fact that the water pipes are being destroyed is nothing new ; as natural causes are sufficient to limit the life of any pipe. Nor does this rusting take place at a uniform rate ; for in some sections a pipe will last for years, while in other sections, where there is no possibility of electrolytic action, the character of the soil may be such, that the pipes will give out in a much shorter time.

Although the injurious action of electric currents is to hasten natural corrosion, nevertheless the fact that a pipe gives out soon after it is laid, is not in itself positive evidence of electrolysis. A careful study of pipes taken from various localities and of specimens which have been produced artificially in the laboratory, has shown that it is very difficult to distinguish between ordinary chemical action and electrolysis.

The appearance of the scale formed on an iron pipe originally subjected to oxidation, and afterwards prevented from oxidation by becoming the negative pole of an electrolytic couple, enables us to determine pretty definitely where natural decay has been arrested by a current of electricity flowing into a pipe. There is, however, apparently no mark showing as clearly where decay has been accelerated by the passage of the current out of a pipe. This gradual deterioration, would appear only in the course of years, and the evil might assume very serious proportions before the evidence became convincing.

We have made careful inspections of pipes taken from a large number of cities, and in most cases we find as stated before that the specimens have the appearance of being acted upon by natural causes, the rate of decay simply being accelerated by the electric current. A few instances, however, have been brought to our attention where no natural decay whatever is apparent ; this sample for instance, is one which was taken from the ground in the vicinity of the power station at Minneapolis. [Exhibited samples.] It is a portion of a gas post service pipe, which led from the gas main running in a direction at right angles to the track. The pipe was in use only about six months, and an inspection will show that no rusting is apparent. Another specimen obtained at Nashville, Tenn., appears quite different, showing the fibrous structure of the metal. This is a portion of a service pipe, and was probably in the grounds several years previous to the time of excavation. It is impossible to state positively whether decomposition in this case was due mainly to electrolytic action, but the natural inference would be that it was, for the reason that the remaining pipes of the system which were laid at the same time, have in most places been unaffected, while in the vicinity of the electric roads very considerable damage has been done.

The class of action that has been most seriously apprehended in Boston is of an entirely different character from that observed in Minneapolis and Nashville. It has not been definitely proven as yet, that the action on the water pipes here is sufficiently serious to menace the system; but the absence of extensive direct evidence of destruction can by no means be interpreted as proving the absence of action.

The soil in this city is presumably saturated to a great extent with salt water, which is a reasonably good conductor of electricity, and which would tend to induce a uniform passage of current from the pipes at all points, instead of a passage of a large amount of current at a few places, as evidently occurs at Nashville, Minneapolis and one or two other cities, where we have made inspections.

Now although in the cases which we have mentioned and in others, the rapid deterioration of the pipes has indisputably been connected with the return currents of electric roads, yet arguments are still advanced to explain the action upon other grounds than electrolysis; such as the permeation of the soil with illuminating gas, etc.

In order therefore, to be able to meet all such arguments as these and to put the responsibility in this matter absolutely where it belongs, we are conducting at our laboratory a series of experiments, with a view to distinguishing positively between electrolytic action, and all other causes of rusting. By this means we shall be able in most cases to determine by inspection, just what part electrolytic action has played in the deterioration of the pipes When this is done we shall be in a better position to pass judgment upon the merits of the various schemes which have been proposed as remedies, for it is absolutely essential to be able to determine from the pipes themselves just how they have been affected by electrolytic action: (i. e. when the pipe was positive to the earth around it); and the other pipe would show the action when the current flowed into it (i. e. when the pipe was negative to the earth around it.)

Now, common salt by electrolysis yields chlorine at the surface where the current leaves the pipe. This corrodes the pipe rapidly. Where the current enters the pipe no corrosive action takes place. These well known facts were borne out by our experiments, which developed, moreover, a point of great practical importance, namely, that the tendency of electrolytic action is to become localized; for the pipes were deeply pitted in spots instead of being corroded uniformly over the surface.

Thus in a typical case a wrought iron pipe 1 inch in diameter lost 7.6 per cent in weight, but the pipe was so badly pitted that when turned off in a lathe to the bottom of the pits, the actual damage was 63 per cent. This shows, of course, that, owing to the formation of the pits, the corrosion had gone in spots to about eight times the depth that it would have gone if it had been uniform over the surface.

At the request of Mr. William Jackson, City Engineer, we have conducte during the past year an elaborate series of tests for the purpose of determinin whether or not electrolytic action had assumed serious proportions in Boston and what remedies it would be wise to apply.

The result of this investigation has recently been embodied in a report, an in order to give a clear idea of what has been done, we will give a few selections.

Nature of Electrolytic Corrosion—Experimentally Studied.

"It was important not only to demonstrate that currents of electricity flowing into or out of iron and other pipes, would produce serious corrosion but to determine just what the character of the injury would be. For this purpose experiments were made in our laboratory, reproducing various conditions in the soil, and the effects were carefully studied.

Samples of commercial pipes were placed by pairs in sand and moistened with salted water. In this respect they were practically under the conditions of pipes buried in the streets.

Measured currents of electricity, at constant pressure, were passed from one pipe to the other of a pair. Thus one pipe would show the action when the current flowed out of it.

Existence of Necessary Conditions for Electrolysis.

If we could ascertain by direct means whether currents of electricity were flowing from the earth into the pipes or from the pipes into the earth, how large these currents were and how they were distributed over the pipe surface, we should then have a direct means of estimating the injury done to the pipes ; but these three points are from the nature of the case very difficult, if not impossible, to determine, even roughly. It is essential, therefore, to proceed indirectly by showing that the underground electrical conditions in the city are such as either to render destructive electrolysis likely, or to render it unlikely. We have done so as follows :

By extended tests we have shown that the distribution of electrical pressure in the earth in Boston is such that there must be a continual, and at times a strong flow of electricity through the earth, from nearly all parts of the city toward the West End Power Station on Albany Street.

In as much as water and gas mains are imbedded broadcast in the soil and are much better conductors than the soil, bulk for bulk, a portion of these currents must traverse the pipes ; and since there is practically no metallic connection between the pipes and the railway returns, the current must enter and leave the pipes by way of the earth. Wherever the current thus enters or leaves a pipe electrolytic action takes place. This produces corrosion where the current leaves the pipe.

This inference is confirmed by multiplied tests which show that the piping is almost everywhere at a potential different from the earth around it, and from the nearest railway tracks. Under such conditions currents must be flowing either to or from the pipes. These differences are, moreover, not constant, but are continually fluctuating, which adds to the certainty of the flow of current.

The demonstration of the continual flow of current through the earth to the power station was made by measuring the difference between the electrical pressure in the water piping at a point near the station and at other distributed points. These outlying points showed always higher pressures than the one near the station.

To demonstrate that these differences of potential are due mainly to the return currents of the electric roads, and to study more completely the character of these currents, an attempt was made to construct a potential map of the city. To obtain the necessary data for such a map wires were strung about the city, radiating from a centre of distribution where readings could be taken. This centre of distribution was chosen on East Street. From that point wires were run along Albany Street to the Power Station, across the city to the Common, and thence to the river at the foot of Charles Street, along Atlantic Avenue to a point near Long Wharf, and tap circuits from these lines extended to several other points. The terminals of all were grounded so that, by simply connecting in a voltmeter at East Street the difference of potential between any two points could be read. Measurements were taken continuously at intervals of thirty seconds throughout the day, and curves plotted with the voltage as ordinates and time as abscissae. The average of a number of days shows that the voltage increases as the number of cars in service increases and the fluctuations are in direct proportion to the load. The accompanying curve will serve to illustrate these facts. This curve is plotted from readings taken between Summer Street and Engine House No. 3, and shows that during the night up to about 5 o'clock in the morning, no appreciable difference of potential exists. As soon, however, as more cars begin to run, a difference of potential between these two points appears, and this difference increases gradually until it assumes a maximum in the morning at about 8 o'clock. Then the difference decreases until about 10:30, when it increases again, reaching a maximum at about 11:30. After this there is a gradual falling off, reaching a minimum in the middle of the afternoon, and then another maximum point at about 5:30. Then there is a slight fall, and another maximum at about 7:30 in the evening, and finally a minimum, followed by a maximum at about 10:30.

From this curve it is easy to trace the movements of the people in the city. The first maximum occurs at about 8 o'clock, when the majority of people are on their way to the offices and shops. The next maximum occurs at noon and the next is reached when the people are on their way home from work at about 6 o'clock. The next point of high potential occurs at about 7:30 o'clock, when they are on their way to the theatres and other places of amusement, and the last maximum is reached at 10:30, about the time that theatres close and people are returning home. These periodical fluctuations occur with such precision, that it would be possible for an observer stationed at a point where what was going on without could not be seen, to tell approximately the hour of the day from these fluctuations.

This shows conclusively that the difference of potential existing in the earth, is due mainly, if not entirely,. to the flow of current from the electric cars back to the power station. A large number of readings of differences of potential taken at various points throughout the City of Boston show a maximum of about 18 volts. This difference occurred between the power station and a point some 5,000 feet away, being in line with what is probably the heaviest flow of current back to the station. A number of readings were taken between different points of the city situated about equally distant from the power station which showed no difference of potential whatever, except at intervals, the difference depending upon the relative position of cars upon the adjacent lines, and often changing rapidly from positive to negative.

We are not aware that systematic measurements have been made in any other city than Boston, so we are unable to state whether or not the differences that exist in the cities which have been more seriously affected are greater than here. The natural inference would be that this is the case, and a few measurements taken by us in Peoria for the purpose of mapping out a small district, seem to show that in places where the electric railway company has not been so careful in bonding its return circuit, the flow of currents through the earth is much greater.

In one or two cities which have been brought to our notice the surface differences of potential appears to be very much greater than here, but this is probably due to the general character of the soil. At Nashville, Tenn., for instance, there is only a few feet of soil below the surface of a greater portion of the city, everything below that being a solid bed of rock. In this case the current naturally flows through the thin layer of soil at its point of greatest conductivity; and hence the current density per unit area must necessarily be increased, which would increase correspondingly the difference of potential from point to point. This probably accounts in part for the rapid action in that city.

The Effect of Electric Currents upon Pipes with Poor Joints.

There can be no doubt that the pipes of this city are at present carrying currents of electricity. This is shown by the fact that we find a continuous difference of potential between the hydrants and the ground ; for, if the pipes did not carry away the electricity this difference of potential would immediately fall.

Now, while it may be possible to control the polarity of the pipes, it is highly improbable that the conditions will ever be made such that the pipes will become exactly neutral. Unless some scheme is developed which is radically different from any yet suggested, currents of electricity in the pipes cannot be prevented, although they may be considerably reduced. For in the system now in use in this city, or in any single trolley system which uses the uninsulated rails as a part of the return circuit, it is inevitable that some portion of the current must pass back to the power station by way of the pipes, as we have pointed out before. Nothing but a system which is insulated from the ground throughout can prevent differences of potential in the ground and the consequent flow of electricity through the pipes. Again, in some remedies which have been suggested, it is proposed actually to use the pipes as a part of the return circuit, so forcing a considerable quantity of electricity to pass through them.

Now, if the current passing along the pipe meets a joint which is electrically poor, that is, a joint which offers considerable resistance to the passage of the current, there will be an injurious action on the pipe, and for this reason: The electricity will not stop at the poor joint, but will divide, part going through the joint, and part passing around it through the earth on the outside or through the water on the inside. The usual corroding action takes place on the inside as well as on the outside of the pipe wherever the current leaves it. This we have shown conclusively by tests conducted at our laboratory.

Hence we must determine the conditions under which this injury from the current passing around a poor joint, becomes a minimum, or how it can be entirely prevented.

With regard to new piping, the question is simply whether lead joints can be made of sufficiently low resistance to hold practically the whole current in the pipes, and not to allow any appreciable part of it to pass around the joints.

In old pipes, however, which have been for years under ground, many joints of high resistance will undoubtedly be found, at which serious injury to the pipes would be occasioned; but it will be possible in most cases, by measuring the fall of potential along the pipe, to locate these joints.

But, besides the injury from corrosion at the joint there is another point which is likely to become of vast importance, and which will render extreme care necessary. This is the possible contamination of the water supply by the salts of iron or lead which would be formed if electrolysis should take place inside the pipe.

For example, suppose in a certain section of the city a supply pipe leading to a building at some distance from the mains does not happen to be used; or suppose a section of the city is shut off during the repairs; or suppose for any reason the circulation of water becomes sluggish; then if there happens to be a joint in this part which is electrically poor, and through which a current of electricity is forced to pass, we should expect the following result: The current would divide, part passing around the poor joint through the water on the inside, as well as through the earth on the outside, as we have explained above. The usual action which occurs when the current leaves a metal will take place on the inside of the pipe, that is, the pipe will be corroded, and if the pipe be iron, salts of iron will be formed and remain in the water. These salts of iron will tend to increase the conductivity of the water, which will cause a greater current to leave the pipes, which, in its turn, will increase correspondingly the rate of formation of the iron salts.

Now, under this action, the water will soon become exceedingly impure, and these impurities by diffusion, will penetrate back into the main piping system.

By this means it is not at all improbable that the water in a portion of the city might be rendered absolutely unfit for many industrial purposes, or should salts of lead be formed no one can foretell how serious the result might be, if the water were used for drinking.

POSSIBILITIES:

In the course of the study which we have given to this problem, we ha developed a number of theories which seem to us sufficiently probable warrant a thorough investigation.

One in particular is especially worthy of mention as it gives promise, properly worked out, of results which would be of great commercial valu This is the theory that by properly using the ground currents, they can b made to protect whole water piping systems from rusting, and thus great lengthen the life of the pipe

It is a well known fact that in the electrolytic cells which are used for such purpose as the decomposition of common salt, the negative electrode is completely protected from the corroding action of the salt solution in which it i immersed.

Again in electroplating the main principle depends upon the formation of metallic deposit upon the negative electrode with a consequent increase in th weight.

We would also cite the well known methods of protecting boilers or iro tanks from rusting, by means of a plate of zinc suspended in the liquid, which in reality serves to protect the tank in the same manner,—namely by rendering the iron of the tank negative to the liquid which it contains.

Now the conditions existing throughout the city do not differ essentiall from those of the electrolytic cells. The voltage is usually somewhat less in the ground, although at times it may be greater. The chemicals involved ar of a greater variety, and the action takes place in damp earth instead of in free liquid. But these differences do not affect the principles of electrolysis.

All the experiments which we have made upon iron and lead pipes, reproducing the conditions of electrolysis in the soil have shown that while the positive pipes were badly corroded, and in most cases practically destroyed, the pipes which served as the negative electrode were in no case injured. Had the pipes been allowed simply to remain in the sand, with no electricity passing between them, both electrodes would have been considerably rusted, as the sand was damp and contained a small quantity of common salt and carbonate of soda.

From this reasoning we feel confident when the pipes form the negativ electrode, in other words, when they are negative to the earth surrounding them, that they are not only, not injured by electrolysis, but that they are actually being protected from natural corrosion. That is, new pipes which have just been put under ground, are better protected from corrosion when they are negative to the ground, than by any of the so-called "Anti-Rust" processes yet devised. And in old pipes which have been under ground for years, all further rusting is stopped as soon as they become negative to the ground.

Whether the pipes are really thus protected and to what extent this protection might be carried, are points which we consider worthy of careful investigation. The few inspections which we have already made upon excavation about the city seem to confirm the above theory.

We have, therefore, outlined a series of tests to find the minimum difference of potential which will oppose natural corrosion.

REMEDIES :

Let us now consider the schemes that have been proposed as solutions for the problem, which for convenience we will divide into three classes.

1. Those accomplishing the result completely.
2. Those giving partial relief.
3. Those which are useless.

1. COMPLETE REMEDIES :

The remedies which would completely do away with the injury to the pipes are:

(*a*) Double trolley system.
(*b*) Storage battery system.
(*c*) Completely insulating the pipes.
(*d*) And possibly the use of the alternating current.

DOUBLE TROLLEY AND STORAGE SYSTEM :

The double trolley system, which is self explanatory, furnishes current to the cars by one trolley wire and takes it back again to the power station by another. The storage battery system is complete in itself. Hence by these two methods no current is allowed to enter the ground, and so no injury to the pipes could result. But practical difficulties arise in the operation of both of these systems which prevent the general use of either of them for the present.

The double trolley is inconvenient to handle, and necessitates complicated overhead construction. Storage batteries are heavy, and are not as yet sufficiently developed for commercial use.

INSULATING THE PIPES :

By the method of completely insulating the pipes, it is evident that the electric currents could not enter them, and therefore could have no effect upon them. For doing this it has been proposed to lay a double piping system consisting of the iron pipes enclosed in drain pipes, or to lay the iron pipes in wooden boxes containing tar or sawdust. This remedy would be successful only in so far as the insulation was complete. Some application of it might perhaps be made to new pipes, but it would hardly be feasible to apply it to a piping system already in the ground. Should this method be attempted one point in particular would be essential to its proper working. The outer system of piping must be absolutely water tight, or the whole scheme would be rendered useless; for should moisture collect inside the insulating pipe, electrolytic action would immediately begin; and as the collection of moisture is likely to take place in one spot, the electrolytic action would be greatly localized, and would therefore take place at a rapid rate. In this connection it might be well to note that pipes which have been laid with an outer covering of cement, have not been at all protected, inasmuch as when the cement becomes moist, eloctrolytic action takes place through it.

ALTERNATING CURRENT:

The alternating current might prove a solution of the difficulty, althou this is still questioned by some authorities. At present the alternating mot is not sufficiently developed to render this system practicable.

REMEDIES GIVING PARTIAL RELIEF:

The remedies which have been suggested with the idea of reducing the acti to a minimum are:

(a) Very heavy returns from the tracks to the power station with good bon between the rails; also returns from sections of track, every 500 feet along t route.

(b) Three wire system.

(c) Insulating the tracks.

HEAVY RETURNS:

The better the system of ground returns the less will be the current flowin through the earth, as it will be confined mainly to these returns; but as w have brought out above, this can never do away entirely with the electric cu rents in the pipes. Heavy returns accompanied by good bonds have undoubt edly diminished the trouble in this city, but have by no means stopped it, an until further experiments have been made, it is difficult to say how muc benefit has been derived. To thoroughly carry out this system the cost fo copper returns is likely to be enormous.

THREE WIRE SYSTEM:

With regard to the three wire system little is actually known, as it has not a yet been sufficiently tested in practical operation. Undoubtedly the troubl would be considerably reduced by this means, but as the system practicall never could be balanced perfectly, currents in the earth could not be pre vented. And in addition to this, the action would be greatly scattered, an made so indefinite that it would be impossible to tell anything about it.

INSULATION OF TRACKS:

A perfect insulation of the tracks is impossible inasmuch as the top surface must always be exposed, so the scheme of insulating the tracks and connecting them by insulated copper returns to the power station, would at bes only tend to reduce the injury. So far no suitable material has been devised and it is doubtful if any material would prove sufficiently durable on account of the severe treatment to which it would be subjected.

3. SCHEMES WHICH ARE USELESS:

(a) Connections from the track to the pipes

(b) Bringing the pipes to uniform potential by the cross connecting wit copper wire, or by motor generators.

(c) Reversing the current at frequent intervals.

CONNECTIONS BETWEEN TRACKS AND PIPES:

So long as the trolley is positive the current flowing from the tracks int the pipes does no injury to the pipes; hence all connections between th track and the pipes are useless, and only tend to raise the potential of the pipes, so that the current will have a greater tendency than before to leave them. The capacity of the return circuit might indeed be increased by connections from the tracks to the pipes, but as this raises the potential of the pipes above the ground, it would result in more injury to the pipes than benefit from the increased capacity of the return circuit

CONNECTIONS BETWEEN PIPES:

All methods which aim to bring the pipes to a uniform potential by copper wires are useless, because this cannot be done. The copper connections only increase the conductivity of the system as a whole, which would reduce the difference of potential between any two parts, but the potential difference could not, by this means alone, be reduced to zero.

Such methods as using motor generators which should regulate the polarity of the pipes, keeping them as nearly as possible to zero, would be entirely out of the question with so complicated a system as the underground pipes of a large city.

REVERSING CURRENT AT INTERVALS:

We have shown by tests at our laboratory that reversing the current at intervals of hours or days is absolutely useless, as the injury to the pipes occurs just the same.

In the foregoing consideration of the schemes proposed as remedies, we have omitted one for the purpose of discussing it more in detail. This scheme is, briefly—to connect the pipes to the negative plate at the power station.

In several cases this scheme has been tried, more or less completely with beneficial results, and its application to telephone cables is ably described by Mr. I. H. Farnham in his recent article upon this subject. But by this means currents of electricity would be forced to flow through the pipes. Hence, before this remedy can be applied to water pipes, it must first be shown that there will be no injurious action at the joints. This we have discussed before.

If it should prove, however, that injurious action at the joints can be prevented, and if we can show conclusively that the pipes are injured only where they are positive to the ground and are protected from rusting where they are negative, then the object of this remedy becomes evident. It is simply to make the pipes everywhere negative to the ground and to keep them so. To do this the trolley must be positive, which will make the ground in the outlying districts positive, and in the districts where it is shown by hydrant tests that the pipes are positive, copper returns must be run to the negative plate at the power station, until all these pipes have become negative.

If the copper returns from the rails direct to the negative plate be of too low resistance, it is likely to render it difficult to make the hydrants throughout the city negative.

Having once made all the city pipes negative they will have to be constantly watched to see that they remain so; inasmuch as the distribution of the ground currents is likely to change, whenever new lines are run, or the distribution of cars changed.

When it is found in any locality that the pipes have become positive more copper returns must be run from the negative plate at the power station, until these pipes have again become negative.

The original expense for copper returns, together with the expense for constant supervision and for running extra returns when necessary, may be considerable; but it is likely that this will be more than covered by the saving in repairs, should the theory of the protection to the pipes be true.

Summary.

In this discussion we have shown that the existing conditions are suitable for serious injury to the piping system from electrolytic action; and in numerous instances we have positive evidence of this injury, We have connected these conditions beyond question with the return currents of the street railway. Nevertheless, it is absolutely essential in treating this problem to be able to determine from the pipes themselves the difference between electrolytic action and natural corrosion.

We have shown also that when electricity is forced to pass through the pipes trouble from the contamination of the water supply is likely to occur.

We have pointed out that by properly using the ground currents it is possible that they can be utilized to protect the whole piping system from rusting.

With regard to the remedies a word more will be sufficient. Undoubtedly the violent action has been much reduced by several of the schemes which have been tried. But notwithstanding this, long and careful investigation will be necessary in order to determine just how far these remedies are efficient, and what further developments now unlooked for may appear.

DISCUSSION.

Mr. Farnham. Mr. President and gentlemen: I came here at the invitation of Mr. Fuller, who knew I was interested in this subject and would probably be glad to listen to the paper, which has been an interesting one to me. It is long and complete, and I hardly feel as though I could add very much to it. There were two or three points suggested, however, which it occurred to me might be made a little clearer, or that might be added to slightly

Considerable space was given in the opening of the paper to the difficulty of determining whether pipes are exposed to or are undergoing the effects of electrolytic action. This may be true when we take a piece of pipe and examine it, look at it; but, of course, the practical question is, are the pipes in a certain city or in a certain street liable to this action; and I think that the writer of this paper which you have listened to, although not making it very clear, would agree with me that this is perfectly easy to determine. It is simply a question, as he has in a way pointed out, whether those pipes are electrically positive to the earth or negative. This can be determined readily by a volt meter measurement which any electrician can make.

Now, if one wishes to go further than this in that experiment, he needs only to place by the side of a water pipe, or any other pipe which he mistrusts may be subjected to this danger, another piece of pipe, a short piece, and leave that disconnected entirely from the main pipe. You will see by that means you have there two pieces of pipe, both of them subjected to the same natural causes of decay, and still only one of them is electrically connected to the system of pipes. If, now, the one which is electrically connected to the system shows a greater corrosion, or more deep pits in it than the other piece, it is evidence without dispute that electricity is doing that work.

I suppose that Boston was the first place where this action upon pipes was discovered and proved to be true, and I suppose it was the telephone cables which were first found to be undergoing this danger and damage. This was found early, very early, in the year 1891, and since that time it has been part of my duty to study this subject which is certainly a very interesting one.

Some of the very first experiments which we made to settle the question were in line with those I have just described. We placed two pipes side by side in a telephone manhole (which is the place in the street where we get at the cables). We placed them upon the ground, connected one of them by means of wire with the cable system, which would allow such currents as would naturally pass from the pipes to the ground to pass through this piece of pipe; the other piece we left disconnected, and in the course of a few days or weeks we examined the two pieces of pipe. The greater corrosion being found upon the pipe which was connected electrically proved without doubt that electricity was the active cause.

Taking Mr. Stone's paper as a whole, I doubt not one would get the fact from it, that electrolysis of pipes could be determined, but in the first part of his paper it seemed to me that he left it a little uncertain as to whether certain pipes were electrolyzed or were simply rusted out from natural causes. I think it is perfectly easy to determine which is operating, and to what extent each cause is operating.

I was interested in that part of the paper which dealt with the poor connections in the water pipe joints. There is no doubt at all as to this fact, that, although the water pipes are put together with a lead ring and caulked quite thoroughly, so the electrician might expect a fairly good electrical joint, there are usually very many very poor joints, so that connecting the pipes to the negative pole of the dynamo in the power station is not sufficient to remove the danger of electrolysis. If the pipes were continuous, so that the pipe became a good electrical conductor, a heavy connection at the power station would ordinarily prevent corrosion. Measurements in Boston and the other cities prove without any doubt that the joints of pipes have comparativ poor electrical joints, and, therefore, a single connection at the power stati is not sufficient.

So far as telephone cables are concerned, we find the method of connectin the cables to the negative pole of the dynamo within the district which is dangerous the most advantageous. It may be interesting to you to point out brief what I mean by the dangerous district. If the dynamos are operating wit the positive side to the trolley line, as ordinarily they are, naturally there is district near the power stations, sometimes 1,000 feet in extent and sometime a mile (in Albany we found this district extended a mile in one directio from the power station), in which the disposition of the current is to leave th pipes through the earth and get again to the dynamo through the rails. Thi is the "danger district." Now, this territory can be mapped out in any cit by volt meter measurements, and within this district we have found that large return wire connected to the dynamo is sufficient to bring all the cable to a zero potential or below zero; that is, they will become negative to th earth instead of positive, in which condition the current flows on to them instead of flowing off, and the danger of electrolysis is removed by that means There is no danger where the current flows onto the pipes.

I have more faith in that remedy, just described, when applied to wate pipes than the writer of the paper has expressed. The difference of potentia between two sections of pipe outside of this "danger district," as is found b measurements, is extremely small. If now within the danger district th copper wires are laid to points all through that district and connected frequently, we will say at every hydrant, it is my belief from the work we hav done, that the danger to the pipes will practically be removed. But, as Mr Stone has pointed out, it must be watched continually, for changes in th power or in the handling of the cars will change this danger district. (Applause).

MR. COOK. I would like to ask Mr. Farnham if he considers that the dange district would be nearer the power station with the trolley wire positive tha with the rail positive.

MR. FARNHAM. With the positive side of the dynamo to the trolley wire th danger district will be at the power station and near it.

MR. COOK. And with the rail positive it will be at the extremities of th line.

MR. FARNHAM The opposite would be true; the safe district would be nea the power station, and the outside district would be the danger district, an in that case the danger district would be very much larger in area.

MR. COOK. Then the safest way is to have the trolley positive?

MR. FARNHAM. I think so, for two reasons: It gives you an opportunit to handle the trouble by a large return wire to the station; that is my firs reason The second is, it would seem to me much better to confine dangerou action to a small territory, even though the local damage be more rapid in tha territory, than it is to have it slowly going on over most of the city Take Boston, for instance, as an illustration of that. At the Albany Street power house, the danger district extends out about 2,000 feet in each direction, in three directions we will say, making the power house the center. All of the rest of the city, today, except those districts which lie near the East Cambridge power station and the Allston power station, are free from any danger. Now, if you reverse the current, which has been done in Boston (so we know by tests and not by theory), the safe district is only this small district of about 4,000 feet in diameter, while the city at large is the "danger district."

Mr. Cook. Why I asked the question was, that in my city the positive current goes to the rail. I have been unable to find any trace of the current near the power station, but I have found it at the outside limits, that is, within 500 or 1,000 feet of the terminus of the railroad track.

Mr. Farnham. That is exactly correct. The railroad in this city was operated in that manner when this corrosion was first discovered, and in order to remedy it, or to make the remedy more easy, a reversal was made. But in most cities the railroads have always operated with the positive side to the trolley; there are a few exceptions.

Mr. Fuller. I would like to ask Mr. Farnham whether, if some other material than lead was used in making the joints, something that is a better conductor of electricity, there would be any less danger?

Mr. Farnham. Mr. Stone in his paper has suggested something in this line. I think unquestionably if the single trolley is to be used, and the currents return to the earth as at present, it would be an advantage to connect the sections of pipe thoroughly electrically; that is, to make a joint that is electrically good, which could be done by a heavy copper bond, or by any other thoroughly metallic connection. The pipes as they are laid now are usually covered with paint, asphalt, and then this ring is put in, which is not a good metallic connection. If they can be connected metallically by a large surface, then the danger to the joints will be removed and the remedy can be applied at the power station much more certainly than at present.

Mr. H. C. Forbes. I think it might be interesting in this connection to say a few words. The West End Road have adopted the method of running their trolley positive, and have made a connection from the pipes to the negative plate of the dynamo. That is the way I understand it. Well, now, in spite of this, on account of the complicated system of piping, we find, as Mr Farnham says, that in the danger districts the hydrants are positive; but we also find positive hydrants scattered all over the city, due, undoubtedly, to points at which the pipe is somewhat disconnected. So I do not think the rule will obtain so definitely when the piping system is as complicated as it is here.

Mr. Winslow. There is one fact which has been mentioned, and that is that the current does a great deal of damage to the pipes which must be repaired by the corporation or municipalities in charge of the works, whether gas or water, and the railroad companies are getting the benefit of it. Now, it see to me that as soon as possible the companies should be prevented from doi the mischief. Under the present conditions it does not seem to be possible stop it practically. But according to the paper which has been read, there a two ways of partially, if not wholly, preventing the current from entering t earth at all. One is, the double trolley and the other is the storage batte system.

Now, with the present trolley system the current goes out, at least I will a sume it goes out, on the trolley, goes through the car to the ground and then back to the station. The return wires and rails are supposed to take the mo of the current, but they evidently do not. Now the resistance of the rail a of the return wire is very slight indeed, and the resistance of the earth is co siderable, but still enough of the current will leave the rail and wire and through the earth and take to the water pipes to destroy the pipes. My id in regard to that would be to stop it altogether if possible.

I can see no reason why a double trolley system would not operate the sa as on the ordinary metallic lines for telegraph instruments or fire alarm sy tems, with which I have had a little more experience. Now, on fire alar work, let the limb of a tree, which has considerable resistance, touch a wi and some of the current will be deflected and return to the earth. So it a pears to me that the double trolley system will not entirely prevent the curre entering the ground and injuring the pipes.

It appears to me that the best system so far as the prevention of injury the pipes is concerned is the storage battery system where the current is give and received and has no distance to travel, from the generating point back the place where it is generated. It is said that the storage system has not y arrived at that state of perfection which will enable it to be used with an economy. And here we reach the very point which I desire to make. If it i more economical to run the cars by the single trolley system then let the railroad companies pay the cost of damage to the pipe systems. When the car are run by the storage system, the current simply passes from one wheel t the other, or across the track, and is thus confined in a very limited space while with any other system it has a chance to travel the length of the line whatever it may be.

Mr. Thomas. There have been electric cars running in Lowell since 1889 and I have never yet known a case of electrolysis of a water pipe, and haven't heard of any effect on the gas mains. We have here with us as a representative of the Lowell Water Board a man who has been connected with th electric railway in Lowell, and he probably can throw some light on how the are able to manage there so that our water pipes have not been affected b electricity. I will call on Mr. Fell.

Mr. Fell. The electric road has been in operation in Lowell since 188 About five miles of the road was built at about the the same time they start in Boston. Our ground wire was very small at first, and we found the diff culties which have been mentioned here. Today 45 miles of electric road are use in the city of Lowell. About three years ago heavier return wires we put in and we also have a connection every 1,000 or 2,000 feet to an overhead wire, by which we return our current to the station. At some points, in the center of the city, the cars are run every half minute, or oftener. Of course the street is full of water and other pipes, but we have never experienced any difficulty, although, of course, I have read of the trouble in Boston and other cities, notably in Minneapolis, where the road is a comparatively new one, built two or three years ago. As I am connected with the water works I would have been very likely to have heard if any trouble existed. I have met Mr. Farnham in Lowell, and we have discussed the double trolley system and the single trolley system. I have considered that the nearest we want to come to a double trolley system is to have an overhead return conductor, and we have found that this not only carries the current better, but assists us in our power, at least that is what our engineers report. I am not practical enough to go into any argument about it. I can simply say, being a member of the Water Board of the City of Lowell, that as far as the Water Board is concerned, or any corporation in the city which is running pipes in the ground, I know of no cause for a complaint against the railroad company in our city.

Mr. Fuller. I would like to ask Mr. Farnham if there is some easy and practical way by which the Superintendent of a Water Department can tell whether his pipes are in any danger, and also whether in his opinion it would be wise to institute some examinations from time to time in regard to whether the pipes are being affected by the electric current?

Mr. Farnham. Mr. President: If I am not taking time which does not belong to me, I will say that I think it is entirely practicable. As Mr. Stone and others have pointed out, it is only necessary to know whether the pipes are electrically positive to the earth or negative. If they are positive, the current is passing from them to the ground. If the current is passing from them to the ground, then electrolysis is going on. Of course, you may find a place like Lowell, or any other city, in which the pipes have not yet been eaten through, but is certainly no evidence that the action is not going on. A voltage measurement, which it is a very simple thing to take, made between the hydrant and the moist earth, or better still, between the pipes themselves, and the moist earth surrounding them (excavating the earth where you wish to make the examination), will show you at once whether they are in a dangerous condition or not. It has been proved that a very small amount of current, that is a very small difference of pressure between the pipe and the ground, is sufficient to cause the action—not so rapidly as if the difference was greater, but any difference of potential will cause the action. If your pipes are positive to the ground, they are certainly being corroded; if they are negative to the ground, they are certainly not being corroded by electricity.

Mr. Cook. I would like to have Mr. Farnham explain how to test by a galvanometer, and to tell by the way the needle will follow whether the current is positive or negative.

Mr. Farnham. A volt meter is the simplest instrument to use; it is one form of a galvanometer. (Mr. Farnham illustrates his remarks by a sketch upon the blackboard showing a simple galvanometer or volt meter.) Unless there is considerable current flowing a simple galvanometer will hardly give motion enough for you to be certain of its movements. For your purposes a "Weston Volt Meter" is desirable.

Mr. Winslow. I would like to ask in regard to that simplest form of galvanometer which you speak of; whether you pass a coil of wire or simply a straight wire under the compass?

Mr. Farnham. Simply a straight wire. If we wish to increase the sensitiveness of the needle, we will wind the wire right around the instrument as many times as we please, and then carry it on. The simplest form is simply passing it under straight. It is perfectly easy to make these measurements, and if you feel uneasy about your pipes you had better make the test ; if you find they are negative to the ground or wherever they are negative, they are perfectly safe ; if they are positive they are in danger.

Mr. Chase. There is one point which has not been touched upon in this discussion, and that is, after we discover that the damage is actually being done, what are we going to do about it? Assuming a case where the water works are owned by a private corporation, that question is particularly pertinent. If the municipality owns them it, perhaps, has the power to say to the electric company that it must do something to remedy the damage. Where a private corporation, however, is the injured party, and it has been given certain rights in the streets, given permission to lay its pipes, and later on this new innovation has been given rights, the municipality may perhaps consider that the two corporations have a private quarrel and leave them settle it between themselves. Now, if some way can be devised by which this malicious element can be turned back upon the prepetrators of the mischief, and make them pay the penalty in that way I think we would all be fully as much interested in that as in finding out that the mischief is actually being done. I wish our friend, who has interested us so much already, would be able to throw a little light upon the solution of that problem.

Mr. Allis. I think it has been stated within a short time in one of the engineering journals, that several applications for the use of an electric franchise have been refused the companies on the very ground that they would not agree to protect the water pipes from this danger which we have heard described in such an interesting way today. I have also seen the statement that in England and in Scotland that policy has been adopted, and the companies there are compelled to agree to take care of their electricity so that the pipes of the city shall not be damaged.

Mr. Sparks. I am Superintendent of the Water Department of a company in Brewer Maine, which has a power station in the town of Veazie, situated 4 miles above the city of Brewer. The company operates the Bangor and Brewer Street Railways, and also an electric light plant, and the pumping station and power plant are in the same building, the entire plant being run by water power. To conduct our water to the city of Brewer we were obliged to cross the Penobscot River with a 12-inch main. The main was laid across from the

Veazie Station to Brewer in 1890, and for conducting the return current, the same company owning the water plant and the electric plant, the return wires were connected to the hydrants all along the line of pipe, a distance of about 7 miles. In two or three months after the electric current was turned on the pipe burst in the river in 35 feet of water. In a very short time after the damage was repaired the pipe again burst. The Ward joint had been used in putting the pipe across the river, and none of the joints gave out. In perhaps six months there was another break, not in the joint, but in the pipe itself. These breaks were not in the form of a regular split, as we sometimes have on the land, but they were irregular. In some instances the pipe would break for a distance of perhaps 5 feet, and the break would run nearly around the pipe, there seeming to be no regularity to it.

My company did not think the electric current could possibly be responsible, although I insisted that it was. Finally, the current was carried across the river by means of seven strands of No. 6 copper wire, connected with the pipes on either shore. The old main had been entirely destroyed, and a new one was laid across the river, and since doing that and making the connection as described, I have had no trouble. The original 12-inch main was so affected that in one instance by striking three blows with a striking hammer on a pipe which weighed 100 pounds per foot, a hole was broken through it, without cracking the pipe in any other place. By simply pounding on the pipe pieces as large as the face of the hammer could be broken out, and the pipe cut clear off in that manner without cracking it anywhere else. That length of pipe resembled black lead as much as anything else. At another place where the line crosses a little stream very near the river, seven or eight lengths of pipe have broken in the same manner as the pipe in the river. I finally put wire on to that and carried the current across the stream, and have had no further difficulty there. The trouble seems to have been where the electric current has left the main pipe in the water. Our power station being about two miles above the river crossing, the current has seemed to leave the pipe there and gone to the power station by way of the river.

Mr. Cook. I would like to ask if the break went exactly around the pipe without any pitting at all?

Mr. Sparks. The pipe was also pitted somewhat, but the crack did not go entirely around the pipe. It ran in a jagged way like chain lightning, that is it was very irregular.

CORROSION OF IRON PIPES BY ELECTRI RAILWAY CURRENTS

(From Engineering News, August 9, 1894, Page 117)

At the meeting of the Western Society of Engineers on July 1 a paper with the above title was read by Prof. D. C. Jackson, mer ber of American Institute of Electrical Engineers, of the Universi of Wisconsin. The paper described an extensive series of laborato experiments carried out at the University by two students to dete mine under what conditions electrolysis of iron pipes actually tak place.

In the first place the author took up the claim that the so-call electrolytic action is actually nothing but ordinary corrosion, caus by ammonia, saltpeter, leaky gas mains, etc. The author held th the rate at which corrosion has occurred and the fact that corrosi occurs at points where an electric current is known to leave t pipes is conclusive proof of electric action. There are three ways which the electric current might cause corrosion. (1) By actual ele trolysis of the iron. (2) By electrolysis of chemical compounds the soil, and (3) by electrolysis of water in the soil, the nascent ox gen attacking the iron. An examination of the corroded pipes, ho ever, shows that the action is undoubtedly due to the electrolysis substances held in solution in the water of the soils, with a resultin secondary chemical action on the pipes.

Nearly all street soils contain more or less ammonia, potash a soda salts. Six small electrolytic cells were connected in series u der 100 volts pressure. Each cell contained clear glass sand, mois ened with water containing a nitrate or a chloride of the above chem cals. The anodes of the chloride cells showed the greatest losses an the nitrate cells the smallest losses. The results of the experimen are considered to prove the correctness of the theory of corrosion which has been finally worked out and which is as follows:

In an electrolytic cell with iron electrodes and a soluble salt o salts of the metals of the alkalies or alkaline earths in solution in th electrolyte, the salt is electrolyzed by the current, the acid radica attacks the anode, forming an iron salt, while the alkaline metal form with water a hydroxide at the cathode, liberating hydrogen the

Finally, the meeting by diffusion of these two products precipitates ferrous hydroxide, $Fe(OH)$. As the amount of electrolysis varies with the strength of the current, a comparatively high current will liberate the acid radical more rapidly than it can combine with the iron, the critical point depending upon the affinity of the acid for iron. When this excess is present, the radical forms an acid by combining with water and at the same time liberates oxygen. Neither the acid nor the oxygen can combine with the anode because that is already engaged in the formation of an iron salt with the acid radical, and hence the gas escapes into the air. If the acid is formed in sufficient quantity, it diffuses through the electrolyte, meets the alkaline hydroxide and forms the original salt and water. In the case of chlorides, the nascent chlorine liberated at the anode forms with it a chloride of iron, and if the current is strong enough to form an excess of chlorine it will be dissolved in the water and may, under the influence of light and heat, form an acid and liberate oxygen; or, if enough heat is generated, free chlorine will be given off, as is shown by experiment. All conditions of these laboratory experiments are practically paralleled in the earth, and hence it is safe to say that similar chemical reactions must go on there. Although the composition of street soils is more complex than the electrolytes of these experiments, they contain the same soluble salts, and as these are diffused through the moist earth they must lend themselves to exactly similar electrolytic influences and chemical changes. In fact, where street soils were used in the experiments as the electrolytes of cells which were placed in series with cells containing known quantities of simple and mixed soluble salts, the losses of the anodes were entirely comparable. It is consequently seen that only such measures as will stop the electrolytic action on salts in solution in the soil can be relied upon to stop the corrosion of iron pipes.

Tests were made to determine what minimum voltage was required to cause electrolysis, and are described by the author as follows:

The iron electrodes were inserted in clean glass sand 1.5 cm. apart, and had about 20 sq. cm. exposed area. In the first cell a 1% solution of nitrate of soda was used with a voltage of 1.2. As before, the hydroxide layer was formed. The electrolytic action was plain without any other tests. In the following cells, the existence of action was shown by chemical tests for the iron salt and the alkaline hydroxide. In the second experiment, a 1/3 solution of nitrate of soda was used with 5 volts. The action was at once apparent:

Cell	3	Pressure	.25	Volts		Action in	3 min.
"	4	"	.125	"	"	"	5 min.
"	5	"	.125	"	1-6% solu.	"	5 min.
"	6	"	.05	"	"	"	40 min.
"	7	"	.013	"	"	"	50 min.
"	8	"	.005	"	"	"	1 hr.
"	9	"	.001	"	"	"	1 hr.
"	10	"	.01	"	"		4 hrs. 45 min.

In cell 10 the electrodes were 30 mm. apart and were 40 mm. by 68 mm. in exposed surface. The electrolyte was street soil.

A surprisingly low voltage produced an appreciable electrolysis in the sand cells. The pressure on cell No. 10 might undoubtedly have been reduced to a millivolt without stopping the corrosion, but the resistance of the soil was so high and the percentage of soluble salts so low, that the time necessary to produce action would have been considerable. A Milliammeter showed a barely perceptible reading in the case of the experiments in which very low pressure was used. The observations plainly show that a mere directive force is unnecessary to produce electrolysis, and the corrosion is simply a question of current.

It is impossible to give in a reasonable space even a summary of the great number of experiments which were made, but the following conclusions are directly drawn from them:

1. In no case is the action due to the electrolysis of water. Where oxygen is liberated at the anode, it does not attack the iron.

2. Only a mere directive force in the nature of a pressure will cause electrolysis.

3. The actual corrosion is therefore only dependent upon the actual current which flows, and is as much dependent upon the resistance of the soil as upon the pressure tending to cause the current.

4. Only a minute quantity of soluble salt is sufficient to start the action, and it will then continue as long as a current flows.

5. The gravity of a corrosion of a pipe depends on the amount of current flowing from a given area and the nature of the salts present in the soil, the order of the activity of the salts being (1) chlorides, (2) nitrates, (3) sulphates.

Concerning the effect of frequent reversals of the current, suggested by Mr. I. H. Farnham, as a remedy for corrosion (Eng. News, May 3, 1894), the author found that the reversals would have to occur as often as 15 seconds, which would make it wholly impracticable. The practical method of preventing corrosion, according to the author, is by the alternating current, or a double trolley system, would be a complete preventive, but alternating motors for street railway work are not yet an assured success. Connecting the pipes and rails with heavy cables at points where the former are positive to the latter proves the most complete method of prevention. The conductivity of the track circuit must be properly reinforced by feeders so that an undue drop is not experienced in the return conductors. These track feeders should always be insulated and put on the lines exactly as are overhead feeders, in order to save them from corrosion. The connection of pipes and rails has been practically carried out in Milwaukee, Wis., at a cost of about $8,000, and has apparently done away with the trouble, and has at the same time decreased the resistance of the return circuit. In the Milwaukee system there are about 125 miles of track and over 200 cars in daily operation. The track circuit was originally put down in excellent shape. In the Madison system present indications show that one connection between rails and pipe systems opposite the powerhouse, costing, all told, about $15, would prevent any serious action. The author concludes as follows:

Investigations have shown that when the negative pole or the generator is connected with the trolley, the pipes are positive to the rails over an extended outlying district, and corrosion goes on over a large area, while with the reverse arrangement the dangerous area is concentrated about the power station. The latter method of connection allows the difficulty to be most easily handled, and after the district within which the pipes are positive to the rails has been accurately determined by proper voltmeter tests, frequent connections of pipes and rails should be made within its limits. This can usually be done at a comparatively small cost, the interest on which may be annually saved by the decrease of lost power if the connections are properly placed. The boundaries of this district should be rechecked from time to time, and the corresponding changes in connections should be made, if the tests show that they are necessary. The outlines of the danger district are likely to vary with the growth of the system, and even change slightly with the seasons, and the connecting wires may be eaten away, so that vigilance is here as everywhere the price of safety, but safety may be absolutely secured in most cases.

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ELECTROLYSIS OF UNDERGROUND CONDUCTORS

By Prof. George F. Sever, Columbia University

In the spring of 1903, Mr. L. B. Stillwell, Mr. F. N. Waterman and the writer felt that it was desirable to compile and co-ordinate as much information as could be procured on the subject of the electrolysis of underground conductors, due to the operation of electric railways. It was felt that both the opinions regarding electrolysis and the practice in remedying the same were so diverse that it would be of value to collect all this information and present it before the International Electrical Congress. Through the efforts of the first-named gentlemen the practice of the electric street railways was secured, and all the world's literature, which was available, was collected and put into the form of a digest. The writer collected information regarding the attitude of the municipalities, including such ordinances regarding electrolysis as had been put into effect up to that time. The data was put into tabular form by Mr. Waterman, and through the courtesy of both Mr. Stillwell and Mr. Waterman the writer has been able to present the final results before this Congress.

The data is presented in the five tables which are attached hereto.

Table 1 shows the street railway practice in the United States regarding the use of return feeders and the effect of increasing the capacity of these feeders. The reports are shown from 102 electric railways.

Table 2 shows the recommendations which have been made to 29 municipalities by city and other engineers. The results of these recommendations are shown in a few cases.

Table 3 shows the most essential electrical features of the municipal ordinances which are in force in 12 different municipalities. The inconsistencies in some of these ordinances are remarkable, particularly in the cases of Atlantic City and Altoona.

Table 4 presents a summary of the opinions of municipal officers, as extracted from the letters received from them. Fifty municipalities, widely distributed, were heard from.

Table 5 presents a summary of expert opinion concerning electrolysis. This expert opinion shows many differences in the recommendations as to remedy. It is the writer's hope that the discussion on this presentation may be full and that some definite conclusions may be arrived at for the betterment of the conditions which are known to exist in some localities.

DISCUSSION.

Mr. **JOHN HESKETH**: Being in the position of having had experience on both sides of the problem I have had reason to give the question very close study. There are certain well-defined lines and conclusions from which I think we cannot escape. To begin with, the onus of protecting underground works from electrolysis or from damage by tramway systems cannot possibly be considered as resting on one or the other party exclusively. It must, if it is to be a successful work, be a mutual one. It is impossible for the telephone company, even by the adoption of all known reasonable methods, to protect their works if the tramway company, on their part, neglect well-known methods. Further, it is impossible for the tramway company to so run their system as to avoid damage, if the telephone company or others interested are laying their works in an unnecessarily dangerous manner As an instance· In one case which I have in mind, a water company laid its lead service pipes within six inches of the rails of a tramway system. They invited electrolysis; they got it; and then they complained. Further, there are conditions which are easily imaginable, where a system of water pipes acts as a feeder from the zone in which danger is existent to a zone which otherwise would not be dangerous. In such cases the water-supply company, or the gas company, should so insulate its pipes as to prevent the feeding of danger from the one zone into the other Further, it has been the effort in one or two places to prevent damage by laying down hard and fast rules as to the drop in the return circuit. For instance, the Board of Trade of London laid down an arbitrary figure of seven volts as the maximum difference of potential between the ends of the return. But any figure of drop in the return must take into consideration the length of the line. It is not necessarily the drop along the return that does the damage. It is rather the difference of potential between the return and the other metal bodies in the neighborhood; and yet not altogether so. It is not the difference of potential only, but the capacity for current carrying from the return into the pipe. There may be a huge difference of potential and yet no passage of current into the pipe. There may be a very small difference of potential, and yet a very dangerous current. There we strike another main principle — the method of testing for possible danger, which ought to be clearly defined. It is not sufficient to measure the difference of potential between the pipe and the return. I rather incline to the belief that the method which has during the past year been suggested in Germany, of measuring the difference of potential between the rail and the earth nearest to the rail, is a more correct method. It takes into account the electrolyte between the two bodies.

Recently the Australian Government met in conference the engineers of the telegraph department and engineers representing electric supply industries. In conference, we agreed on certain regulations for the protection of the works of the Postmaster-General of Australia, and the points just mentioned were the salient points brought out in the discussion on the question of electrolysis. When I heard that this Congress was to be held, it appeared to me as rather desirable that an effort be made to have an expression of opinion from the technical associations of different nations on this most important subjejct, and I mention that now for your consideration, if deemed advisable. It is rather a problem as to how such an expression of opinion could be obtained, but it seems to me, in view of the diversity of regulations throughout the world and the lack of authoritative statements based on a scientific principle, that such a statement prepared by scientific bodies would be invaluable to both sides.

Prof. F. C. **Caldwell**: In Columbus, Ohio, as has been mentioned by Prof. Sever, we have made some investigation of this matter, and our conditions there are particularly favorable for absence from the trouble. I believe the soil there is not such as to produce much electrolysis, and the lay of the railway system is particularly favorable for freedom from it. It seems to me there are two points upon which definite information is needed in connection with this matter of electrolysis. The first is whether we should look for trouble only where the current leaves to go to other metallic structures, or whether we are to look also to the joints of the pipes. There is much difference of opinion upon this question. It has been claimed that trouble has been found at the joints, but on the other hand we find engineers taking very decidedly the stand that all that is necessary is to keep the current from leaving the pipes and going to other conducting material. Information on this subject would certainly be very valuable. The second point is as to how much current can be allowed in the pipes or to leave the pipes. This is especially important if it is true that we are to look for trouble at the joints. If we must keep the current out of the pipes practically altogether, then it becomes an important matter to know how much current can be allowed to flow and still not add an appreciable amount to their disintegration. There has been a little data along this line published in regard to the resistance of pipes. What is needed is data as to the resistance in the case of pipes laid in dry sandy soil. Where a pipe is laid through a street, if we make an attempt to measure its resistance we shall get the joint resistance of the pipe, the surrounding soil, and other conducting material, so that we cannot be sure that the resistance we get would show the current going through the pipe.

The other question as to how much damage is to be expected from the current when it leaves the pipe, I believe, depends very much upon the surrounding soil. In some cities much more damage may be anticipated, with the same current flowing, than in others. We have been carrying on, at the Ohio State University, some investigation along this line, obtaining earth from different cities and using an electrode which was weighed before and after the test. Our results so far have not been sufficient to warrant any conclusions, but they are interesting. We have found in two different tests a considerable difference in the amount of material in different cities. Soil from Dayton, Ohio, where there has been much trouble, gave a large amount of electrolysis, while that from Columbus gave a very small amount. It looks as if this was an important point to be considered.

Mr. H. E. **Harrison**: It does not matter practically how much current or what current density flows into a pipe. It has been assumed that the current flowing into the pipe would come out more or less uniformly through the whole service; but I do not believe this is so. The pipe may pass through a considerable length of soil which will be a very fair insulator, and will then come upon a patch of soil that is conductive to a high degree, with the result that the current density is more visible and the damage greater.

Prof. SEVER: The data which we have collected contains many references to underground conductors other than piping systems, so that I think it is perfectly proper that that phase of the situation should be brought before this meeting. About two years ago, when I became connected with the city government of New York, Mr. Jones brought me a cable sheath which he claimed had been destroyed by electrolysis. I know that on some cable sheaths in New York city, both on the telephone and the power circuits, there are large currents coming presumably from the operation of the electric railways. In the Bronx there has been considerable difficulty. In the borough of Manhattan there has been difficulty which to some extent has been remedied by the co-operation of the officials of the railway company and the telephone companies. I know of one instance where the sheaths were bonded at one point by a heavy copper conductor to a return of the Manhattan "L,"—approximately 1500 amperes passed over that wire—sufficient to heat it so one could not put his hand upon it. The Manhattan elevated road uses its structure completely bonded, its service rails completely bonded, and a large amount of return feeder, something like six or seven million circular mils, to get their current back without causing trouble to their own and other conductors. In spite of all their precautions, there are still thousands of amperes coming back on their cable sheaths as well as those of other companies. It has been drawn to the attention of the city officials for their recommendation, as there are at times a higher potential than twenty-five volts between the end of the line and the nearest sub-station, which is the maximum fixed by the city rules.

Mr. P. B. DELANY: It seems to me there is one phase of this subject which has been overlooked, and that is the shunting of water and gas pipes or the cable sheath, by the grounding of telegraph wires in the city. This may, to a certain degree, account for the apparent discrepancies electrolytically, in different cities and towns and through different soils. We all know that there is in many places a very great leakage—what we call stray or vagrant currents—into the telegraph circuits by way of the ground return. I myself have had experience with wires about a hundred miles in length, and it was rather a disagreeable experience. I tried some synchronous experiments four years ago, and I found there was a voltage varying from three or four volts to seventy-five in that circuit—not constantly, but running up and down. If it had been constant, we might have been able to do something with it, but as it was fluctuating, it was rather disastrous to the experiments at the time. It has occurred to me that in cities where there are hundreds of ground connections made at different points to the pipes and where considerable electric energy is used in the operation of telegraph lines grounded in cities, some of the electrolysis may be even due to that source, as well as the protection of the pipes from power leakage by the shunting. I think this suggestion may throw some light on the subject, although I presume that this phase of the case has been taken into consideration by Mr. Sever and his associates. It has not been referred to in the discussion.

Mr. **Bancroft Gherardi**: One of the functions of my department is taking precautions against electrolysis trouble on our cables, and in that connection the bulk of our work has been in Brooklyn, on account of our very large underground plant there and the great extent of the overhead trolley system. It is not unusual for us to have to take care of currents as great as 200 or 300 amperes at a single point on our system. This shows that the aggregate amount of current that our system is carrying back to the power-houses amounts to thousands of amperes. There is a certain expense in connection with this work which is quite appreciable, and there still remains, after everything is done that we can do, a certain amount of trouble which is real trouble. The discussion of the responsibility for such trouble and expense is one that it seems to me is beyond the scope of this section and I shall not touch on it here.

Prof. **Sever**: In connection with the situation on the Virginia Passenger & Power Company, at Richmond, Va., Mr. Stillwell went at the matter in an engineering way by laying out very carefully on paper the whole railroad system, placing the cars in accordance with their various schedules, and ascertaining those points to which he could most profitably connect a return conductor. He decided upon four points about the city, almost at the corners of a rectangle, and carried directly back to the power station very heavy return feeders, as well as heavily bonding the tracks. From the results which they are getting, it would seem that that is a very satisfactory way in that particular locality to solve the problem. Chemical analyses were made also of the soils. I learned from him a short time ago that the city, through its engineering staff, approved of this scheme and accepted the efforts on the part of the railroad company as an expression of a desire to reduce the trouble. As stated in one of the tables which is presented, the city of Richmond insists that the railroad company must pay for all damage to pipes. How two men are going to agree as to whether damage is due to electrolysis or to ordinary tubercular action or rust, I do not know, and I do not know anybody who does know definitely. The other day we took up in Brooklyn cast-iron water pipes, which had been down fifty-two years, so filled with tubercular nodules that the area of the pipe was reduced to about one-half of its original area. In other places we took up lead pipe, part of which had entirely disappeared, undoubtedly through electrolytic action.

Mr. **J. Sigfrid Edström**: We have had very little trouble in Europe from electrolysis. There has been some, however, in the earliest railroads built in England, but lately we have experienced hardly any trouble. I think this is owing to the very solid construction in bonding and in cables carrying return current to the central station. In Berlin the city officials require that there shall be no larger voltage between any two points of the rails in the city system than two volts — that is, between any points in the rail system of the tramway there must be no greater pressure than two volts. This, or a similar stipulation, has been adopted by many other cities, including cities in Switzerland and Sweden, where I have had the pleasure to be a railway engineer. In these places we bond the rails with two heavy copper wires at each joint. We have double track generally, and consequently we have eight copper wires at each double pair of joints of the rails. We bond the rails between each other and also the tracks at certain distances. At crossing of bridges or water pipes, where the rails get close to iron in the earth, we insulate the rail with asphalt as much as possible The rails themselves in the street are generally insulated through a layer of stones or concrete put under the rails. To take the current from the rail, we put it in an *insulated* cable of very heavy dimensions. It is very important to have the cable insulated, as a *bare* copper cable, which I know is often used and which generally is buried deep into the street, invites the current to seek other ways home. The general practice in Europe is that, where a feeding cable is connected to a certain part of the overhead wires, a return insulated cable of the same dimensions as the feeding cable is used. This has also the advantage that in case the positive cable becomes damaged, we can easily exchange it for the return cable until the positive cable has been repaired. All the negative returns are carried into the station through resistances, and these are regulated so that the actual current for which the cable is assigned arrives there; thus the current is split up and no cable is overloaded. In this way every feeding point becomes a "central station" These central stations are planted around in the city, and we have no long flows of current running through the city Street railways built ten years ago in this way have given no trouble whatever

As to disturbances on telephones in cities, where the telephones use the earth as a return, there has been some slight disturbance, as naturally a portion of the street-car current must go through the earth and thus some of it also through the telephone wires. In cities where we have a double-wire telephone system, there is no trouble whatsoever.

Mr. HESKETH: Although, as you stated, the regulations define the drop in voltage, I should like to ask what in actual practice is found to be the approximation to the regulation? How closely in Berlin do they comply with the regulations? It would be interesting to know, for the purposes of comparison simply, some of the leading dimensions of the system on which the regulations mentioned are found practicable — the mileage of track and the number of amperes output from the station per mile of track.

Mr. EDSTRÖM: I am here not loaded with figures, but I will try to give part of the information. When the plant is laid out, it is laid out according to a certain schedule, and consequently you know the loads on the several points of the city. According to this the dimensions of the cables are figured out. The track itself has the ordinary two heavy copper wires at each rail and four rails at the side of each other are considered to be sufficient for the two volts drop that should be the maximum in the city. Actual tests have not been taken, so far as I know. I have myself been opposed to the two volt requirement, as I consider this limit very low and I do not think that on any day of heavy traffic — for instance, Sundays or Easterdays or Whitsundays — that the two volts will be the limit but that you will actually find the drop far larger.

CHAIRMAN JONES: I perhaps might give you a few salient facts of the effect of electrolysis upon the Postal Telegraph. The Postal Telegraph Cable Company would be only too glad to submit any of the data it has upon the subject of destruction of their cables by electrolysis to Prof. Sever for the purposes of his paper. I think they would do this in the interest of electrical engineers everywhere, and in the interest of municipalities whose pipes are being eaten up, and also our good neighbors, the telephone people, who are in the same boat with us in that respect.

I can only, of course, as intimated, speak in a general way on the subject. The telegraph companies were urged to place their wires underground, commencing about the year 1880. Cities got tired of the crow's nests and networks of wires which were in their streets. Some of them were curiosities. Commencing with New York, Philadelphia, and other cities, the agitation became so great that eventually they started to put in their wires underground. As a rule, the cables of the telegraph company are not to be compared with the network of water pipes and gas pipes of cities, nor, except in a few cases, the rails of the tramways. The telegraph companies coming into a city and passing through generally follow a line of pipes, and lately the line of rails of the electric railroads, and we have had a great deal of trouble from electrolysis, in times past, in various cities, commencing with Boston, Hartford, Baltimore, Chicago, Atlanta, New Orleans, and other places. In almost all those places, our cables, that had been laid parallel with or near to the electric railroads, have been attacked, and sections have been eaten up, and our service stopped. We were helpless in the matter, because the cities in some cases had ordered us underground, and after having gone underground, our poles were taken down, and it was not possible to place the poles up again and put the wires on them very expeditiously; so we had to suffer and so the public had to suffer. Its telegrams could not be forwarded until we had made the repairs. We found out, however, that by applying the now universal remedy of bonding, where we could secure a good return wire from the point at which the currents were leaving our cable sheaths to get back to the negative brush of the generating station of the railroad companies, we were rendered entirely immune. We have not had any trouble since we have been properly bonded in any city. Quite recently, in New Orleans, our cable was attacked at one point; but we have since bonded and I think there will be no further trouble. In Hartford we have for some years been bonded, and no trouble has arisen there. In all other places where we have been properly bonded there has been no trouble. It of course follows that the currents which are carried through the trolley pole and down into the motor of the car and so into the rails, is seeking its way back to the generating station, and if the resistance is very high between the point where the car is resting upon the tracks and the negative brush of the machine at the station, it is going to seek a great many ways to get back. It will go all around and follow every route that is possible. As a matter of fact, we loan the sheaths of our cables to the railroad companies to allow them to get their current back to the station, and we bond our sheath to their return wire so they can have every use of it and get back the easiest way possible. We do that to prevent getting hurt.

It is not where their current comes on and starts in to go back that we suffer, but it is where the current leaves our sheath to go through moist ground or some electrolyte to reach the metallic conductor at the power station; so that we have found it was necessary for us to make that path just as good as possible. Our sheaths are one-eighth of an inch lead with 10 per cent of tin, and we have not yet had a case where the carrying capacity has been exceeded by the amount of current that our friends, the railroad people, want to have us carry back for them. It is lying there, doing us no good at all, and we feel no effect from any induction in that respect, and we are glad enough not to be eaten up in the undertaking.

It is pretty difficult to tell whether there is any serious electrolysis generated by telegraph currents or not. Of course, the companies are using much more current now than ever before, on account of their increased business, but prior to the time of electric lights and trolley systems, I have never yet heard of any electrolysis arising from telegraph currents, and do not think they are of sufficient quantity to figure in the case at all.

There is another question, in regard to alternating currents being used for transportation or trolley purposes. How are we going to be effected when alternating currents are used? That is an open question which I am not prepared to discuss, but I would like to call it to your attention.

Mr. L. W. Stanton was introduced by the Chairman and presented the following paper:

SUMMARY OF MUNICIPAL REPORTS ON ELECTROLYSIS.

Number.	State.	City.	Date.	Report to.	Report by.	Was electrolysis alleged?	What pipes were affected?	Was electric railway company blamed?	What remedy suggested?	What remedy applied?	Result of improvement.	Was legal action instigated?
1	Conn.	Hartford	1901	Council	Water Comm'rs.	Yes.	Water.	Yes.	Double trolley.			
2	Conn.	Middletown	1902	Water Comm'r.		Yes.	Water.	Yes.	Better return.	Rebonding	No more trouble.	
3	Ill	Peoria	1898			Yes.	Water.	Yes.	Double trolley.			Yes.
4	Ind.	Indianapolis.	1901			Yes.						
5	Ky	Newport	1902	City	Water Works Com.	Yes.	Water.	Yes.				
6	Md.	Baltimore	1901		Ch. Eng. Elec. Com.	Some		Yes.	Efficient bonds.			
7	Mass.	Chelsea	1902	City	Water Comm'rs.	Yes.	Water.	Yes.				
8	Mass.	Worcester	1901		City Engineer.	No.						
9	Mich.	Detroit	1896	Bd. Water Comm'rs.	City Engineer.	Yes.	Water.	Yes.	Efficient return.	Return feeders.	Reduced P D.'s.	
10	Minn.	Minneapolis.	1901		City Engineer.	Little	Gas.					
11	Minn.	St. Paul	1901	Water Comm'r.	D. B. Maury, G. H. Benzenburg & Co.	Yes.	Water, gas.	Yes.				
12	Minn.	St. Paul	1903	City	Water Comm'rs	Yes.	Water	Yes.				
13	Mo.	St. Joseph	1894		City Electrician	Yes.						
14	Mo.	St. Louis	1903	Water Department.	E. E. Brownell	Yes.	Water, gas.	Yes.	Good return.			
15	N. J.	Newark	1901		Engineer Water Dept.	No.						
16	N. Y.	Albany	1901		Supt. Bur. of Water.	1893.	Water.	Yes.	Return feeders.	+ Drainage	No more trouble.	
17	N. Y.	Buffalo	1901		Chief Engineer.	No.						
18	N. Y.	Rochester	1901	Com. Public Works.	E. A. Fisher	Yes.	Water.	Yes.	Better return.	Better return.	Reduced P. D.'s.	
19	Ohio.	Cincinnati	1899	Am. Soc. Mun. Im.	Com. Water Works.	No.						
20	Ohio.	Cleveland	1899		Supt. Water Works.	Yes.	Water.	Yes.				
21	Ohio.	Columbus		Public Works	F. C. Caldwell				Efficient return.			
22	Ohio.	Dayton	1899									Yes.
23	Pa.	Philadelphia.	1899		Ch. Elec. Bureau.	No.				Efficient return drainage.		
24	Pa.	Reading	1900	Water Com.	A. A. Knudson	Yes.	Water.	Yes.	Efficient return, double trolley.			
25	R. I.	Pawtucket		City Engineers.	A. A. Knudson	Yes.	Water.	Yes.	Double trolley.			
26	R. I.	Providence	1900	Com. Public Works.	A. A. Knudson	Yes.	Water.	Yes.	Efficient return.			
27	Wis.	Madison	1899		City Water Works.	Yes.	Water.	Yes.		Connected track and pipes	No improvement.	
28	Wis.	Racine			G. H. Benzenburg	Yes.	Water.					
29	Va.	Richmond	1899	Supt. Water Works.	A. Schoen	Yes.	Water.	Yes.	Double trolley.			Yes.

SUMMARY OF MUNICIPAL ORDINANCES CONCERNING ELECTROLYSIS.

Number.	State.	City.	Date.	Immediate cause for ordinance.	System required.	Are taps from pipes to rails allowed?	Is drainage in + area allowed?	Is drainage in other areas allowed?	Is railway company made liable for corrosion?	Maximum + P. D. pipes to rails.	Maximum − P. D. pipes to rails.	Allowable leakage of current.	Drop allowed in return.	Drop per mile allowed in return.
1	Conn	Montville												
2	D. C.	Washington			Double trolley or equivalent									
3	Ill.	Chicago	1900							1	1		½-300′	8.8
4	Ill.	Freeport		Franchise					All damage to water and gas pipes					
5	Ga.	Atlanta	1898									No leakage		
6	Mass.	Fitchburg							For all damage					
7	Mich	Battle Creek			Double trolley if demanded	No.				¼	¼	No more than one amp. in any pipe.	⅛-200′	3.3
8	N. J.	Atlantic City	1902			No.	No.	No.	Yes	¼	¼	No leakage	¼-200′	6.6
9	N. Y.	N. Y. city											25	
10	Pa.	Altoona	1902						Yes			No leakage		
11	Pa.	Philadelphia								¼	¼		⅛-200′	3.3
12	Va.	Richmond	1896						Yes					

SUMMARY OF MUNICIPAL LETTERS CONCERNING ELECTROLYSIS IN JUNE, 1903.

Number.	State.	City.	Information received from.	Report concerning electrolysis.	Report concerning electrolytic survey.	Are water pipes owned by city?	Remarks.
1	Ala.	Birmingham	City Engineer	None			
2	Ala.	Montgomery	Mayor	None			Investigation being made by City Elec. Report, October, 1903.
3	Cal.	Oakland	Secretary to Mayor	None			
4	Col.	Denver	Secretary to Mayor	None			
5	Conn.	Bridgport	Mayor	None		No.	
6	Conn.	Hartford	Mayor				President Water Board reports "but little damage"
7	Conn.	Waterbury	Mayor	None			
8	Del.	Wilmington	City Clerk	Only from Water Dep't.			
9	D. C.	Washington	Electric Engineer	1898-9, 1900	Yes		
10	Ga.	Atlanta	City Electrician	None			
11	Ind.	Fort Wayne	Mayor	None			Railway company to take care of all damage.
12	Ind.	South Bend	Mayor	None			
13	Iowa	CouncilBluffs	Mayor	None			
14	Iowa	Dubuque	Mayor	None	None		
15	Ky.	Covington	Supt. Water Works	None			
16	La.	New Orleans	Secretary to Mayor	None	Has received some attention		"We do not believe damage was serious."
17	Me.	Portland	Com Pub Works	None			"We have had very little trouble."
18	Md.	Baltimore	Chief Engineer	None			"Few complaints." "The trouble is generally local."
19	Mass.	Cambridge	City Electrician	Report by C. H. Morse			
20	Mass.	Holyoke	City Engineer	None			"No trouble whatever."
21	Mass.	Lawrence	Supt. Water Board	None			"We have not been troubled in any way."
22	Mass.	Lynn	Clerk	None			
23	Mass.	Malden	Clerk	None			
24	Mass.	New Bedford	Mayor	None	Now investigating		"As far as we know none of our water piping has been damaged to any great extent."

25	Mass.	Newton	City Engineer	By Stone & Webster, 1895.			"Up to present time, there has been little or no complaint." Gas company installed insulating joints.
26	Mass.	Springfield	Mayor	None			"Little complaint of it, but none of importance."
27	Mich.	Bay City	Mayor	A. A. Knudson, 1902			Report not printed.
28	Mich	Grand Rapids.	Mayor's Secretary	None			
29	Minn.	Duluth	Mayor	None			"We have none." "We have never been bothered."
30	Mo.	St. Joseph	Mayor	None			
31	N. H.	Manchester	Mayor	None			"Manchester has never suffered annoyance."
32	N. J.	Bayonne	Secretary to Mayor	None			
33	N. J.	Elizabeth	Mayor	None			"Have had but few complaints."
34	N. Y.	Buffalo	Dep. Water Comm'r.	Report of deputy, 1902			"I have not found a leak." (From electrolysis.)
35	N. Y.	Troy	City Engineer				"We have not been seriously troubled."
36	N. Y.	Utica	Mayor	None			
37	Ohio	Canton	Sec. Water Works	None			"We have had but very slight trouble."
38	Ohio	Cincinnati	City Electrician	None			"It is a condition unknown in this city."
39	Ohio	Cleveland	City Clerk	Water Works Report			
40	Ohio	Columbus	Sec. Bd. Pub. Service	Water Works Rep't, 1901.	F. C. Caldwell		Franchises specify "double trolley or equivalent."
41	Ohio	Toledo	Mayor	None			
42	Pa	Lancaster	Mayor	None			
43	Pa.	Williamsport	City Engineer	None		No.	Have noticed spongy or porous pipes.
44	R. I.	Providence	Com. Dep. Pub. Works.	A. A. Knudson			Railway companies "have taken such steps to prevent electrolysis as best they can and continue to use the single trolley system."
45	Tenn.	Memphis	Mayor	None			
46	Tenn.	Nashville	Secretary to Mayor	None	Now investigating		Suit v. Railway Company just entered by gas company.
47	Va	Norfolk	Supt. Water Dep't	A. A. Knudson			
48	Wash.	Seattle	City Engineer	None	Now investigating		
49	W. Va.	Wheeling	Mayor	None			
50	Wis.	Milwaukee	Ass't City Engineer	None	"No systematic survey."		

SUMMARY OF EXPERT OPINION CONCERNING ELECTROLYSIS.

Number.	Name of expert.	Title of article.	Where published.	Date.	Can electrolysis be sufficiently mitigated with single trolley system?	Most suitable remedy.	Are taps from rails to pipes recommended?	Is drainage in + area recommended?	Is drainage in other area recommended?	Are electric railway companies legally liable?	Remarks.
1	A. V. Abbott	Electrol. from Ry. Cur.	Cassiers' Mag.	1899	Yes			Yes			
2	Baylis	Electrolysis	Canadian Elec Assn.	1894	No	Only cure is double trolley					
3	Wm. Brophy	Prevention of Electrol.	Insurance Eng'r'g		Yes.			No			Suggests insulating pipe joints
4	H. P. Brown	Remedy for Electrol.		1895		Neg. booster					
5	Ellicott		Report in Chicago				Yes				
6	I. H. Farnham		Cassiers' Mag.	1896	Yes		No	Yes	No		Suggests balanced feeder system.
7	Fisher	Legal Status		1894						Yes	
8	A. B. Herrick				Yes	Eff return					
9	D. C. Jackson	Electrol. of Iron Pipes	Street Ry Jour.	1894			+ Area				
10	"	Corrosion of Iron Pipes.	"	1894	Yes						
11	Kalsey		Report to Salt Lake City				Yes				
12	H R. Keithley	How to Prevent Electrol.	Street Ry. Review	1894	No	Complete metal circuit					Advises good bonding for comp met cir
13	A. A. Knudson	Corros. of Metal by Elec.	Amer. Elec-ch Soc.	1903	No	Double trolley					
14	G Low	Rail Bonding & Elec. Corros		1895				Yes			
15	M. R. McAddo							Yes			
16	W. H. Merrill	Electrol. of Buried Pipes	Western Electric	1896	Yes	Double trolley + drainage		Yes			
17	C. H. Morse	Electrol. of Water Pipes	Street Ry. Review		No			Yes			
18	O'Reilly		Report to St. Louis.	1896			With precaution				Almost no trouble in St. Louis.
19	Parshall	Electrolysis	Jour. Inst of E. Es.	1898	Yes		No	Yes			
20	J. Swinburne	Electrol. of Gas Mains	Incor. Gas Inst. Eng.	1902				Yes			
21	Stone & Webster	Rochester Report		1901				Yes			
22	H. C. Townsend		Cassiers' Mag	1895		Double trolley				Yes	
23		Results of Electrol.	Boston Report	1895	Yes			Yes			
24		More About Electrol.	Street Ry. Review	1893	Yes		Yes				
25		How to Cure Electrol.	Street Ry. Review	1894	Yes			Yes			

PART IX

VARIOUS SYSTEMS OF ELECTROLYTIC MITIGATION

There are six distinct forms of electrolytic mitigation for eli inating or mitigating electrolytic corrosion upon subsurface metal structures, as follows:

1. A system of electric street railway which has no portion its total circuit in intimate electrical contact with the earth, or knov as an ungrounded system. The electric street railway surface lin of the cities of Cincinnati, Ohio, Washington, D. C., and New Yoı N. Y., are the only ones in the United States on which this system in operation; also in Havana, Cuba.

2. A system of electric street railway which uses an alternatiı current grounded rail-return system. This system of traction is operation upon the New York, New Haven and Hartford Railro from New York City to or near New Haven, Conn., and in Philad phia from the Broad Street Station to Chestnut Hill and from t Broad Street Station to Paoli, Penna. It is also used possibly by very few interurban electric railways.

SINGLE-PHASE ALTERNATING-CURRENT SYSTEMS FOR RAILWAYS

Single-phase systems now have the following status: They a used with 3,000 to 11,000 volts, and 15- and 25-cycle alternating cı rents for many interurban roads and particularly for the haulage heavy individual train units in trunk-line work. In America, the 11,C volts, 25-cycle system was selected, in 1906, by the New Haven ro for the electrification of its New York-New Haven Division, 73 mil The first half, to Stamford, is now in successful operation, and pla have been developed for its use in all freight and passenger work the balance of the division. The single-phase system is also employ by these other roads: Rochester branch of the Erie Railroad, whi has used 11,000 volts since 1907; Indianapolis and Cincinnati line, miles, since 1904; Baltimore & Annapolis Short Line, 35 miles; Sp kane & Inland Empire Railroad which, since 1906, has used 6,000 vol for ordinary freight and passenger service over 162 miles of trac

Visalia Division of the Southern Pacific Railway; Denver-Bouler branch of the Colorado & Southern Railroad; Rock Island-Galesburg Division, 52 miles, of the Rock-Island Southern Railroad; and Grand Trunk Railway, for the Sarnia-Port Huron tunnel, where 41 freight and passenger trains per day are hauled through the yards and up the 2 per cent grades in the tunnel.—Page 136 from "Electric Traction for Railway Trains"—Burch. Copyright, 1914, by McGraw-Hill Book Co.

Electrolytic action by alternating currents, under the most favorable electrolytic conditions, is never more than three (3%) per cent of that of direct electrical currents of similar volumes.

3. The negative booster system, operating in an all rail-return electrical circuit, or in a pipe drainage circuit, or a combination of both rail-return and pipe drainage electrical circuits. This system is not in use in America today, so far as the writer has been able to learn. (See this report for one diagramatical illustration of this system, Figure No. 5.)

4. A system of copper cables used for draining the diverted, direct electrical currents from a subsurface metallic structure. This electrolytic mitigating system, in principle, is the universal American practice, commonly known as the Pipe Drainage System. (See this report for four diagramatical illustrations of this system, figures Nos. 1, 2, 3 and 4.)

5. A system of copper cables for draining the direct, electrical currents from the rail-return circuit, with and without electrical resistances in the copper cable return feeders, commonly known as the Insulated Rail Return System.

In the City of Springfield, Ohio, a very small portion of the City of St. Louis, Mo., and possibly in one or two more instances this presumed system of electrolytic mitigation has been installed. (See this report for three diagramatical illustrations of this system, figures Nos. 6, 7, and 8.)

6. The Three-wire Trolley System, where one section of the trolley is electrically positive and another electrically negative to a grounded neutral track and rail-return circuit.

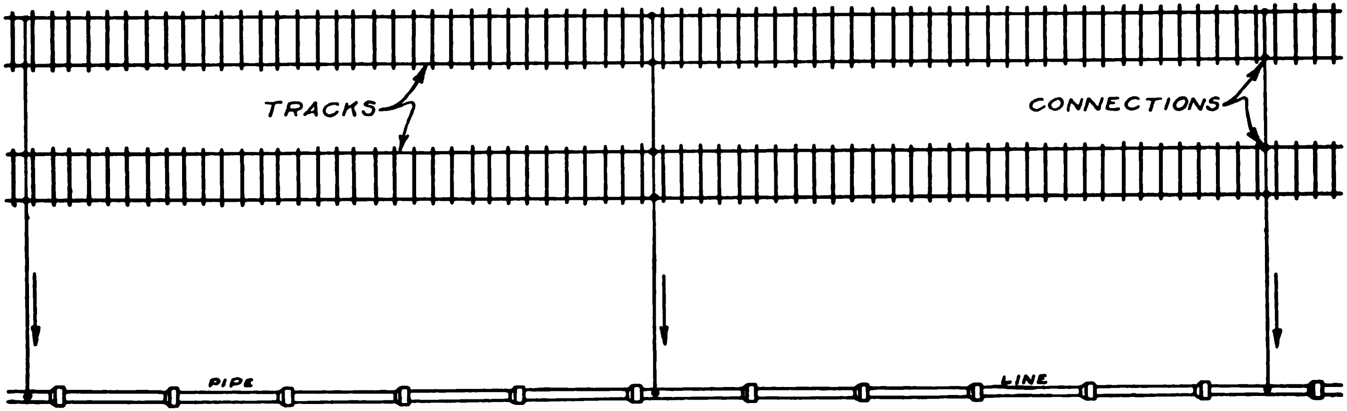
This proposed system of electrolytic mitigation is being experimentally installed in the City of Springfield, Massachusetts and Milwaukee, Wisconsin. (See this report for three diagramatical illustrations of this system, figures Nos. 9, 10 and 11.)

The following diagramatical illustrations are given in the respective order in which they are stated above, and consists of eleven (11) different page plans:

FIGURE 1

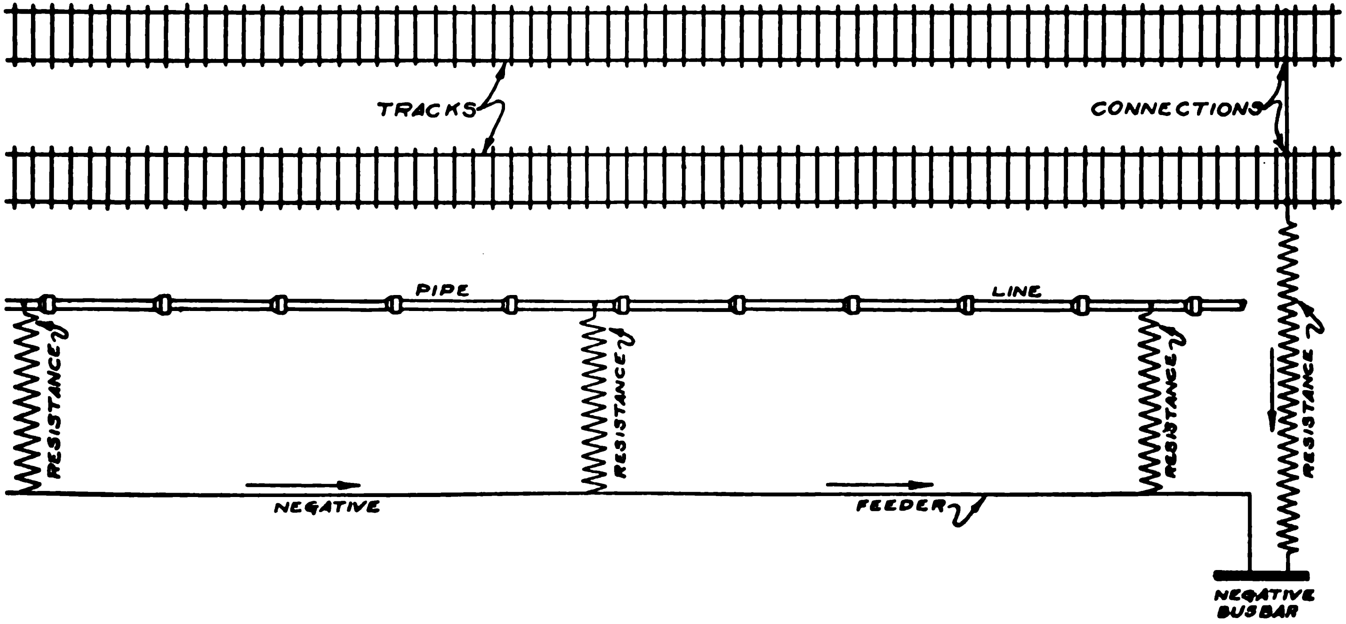
(Diagramatical Plan)

An impractical Pipe Drainage System, consisting of copper cables connecting subsurface metallic structures with the tracks of an electric street railway system.



About 57 of these metallic connections were installed upon the Milwaukee Water Works System, in 1893, by The Milwaukee Electric Street Railway Company. (See O. M. Rau's report on pages 99-102 of this report.)

A practical Pipe Drainage System, consisting of connecting copper cables between subsurface metallic structures and negative busbar, with additional electrical resistances in both pipe and track connections.

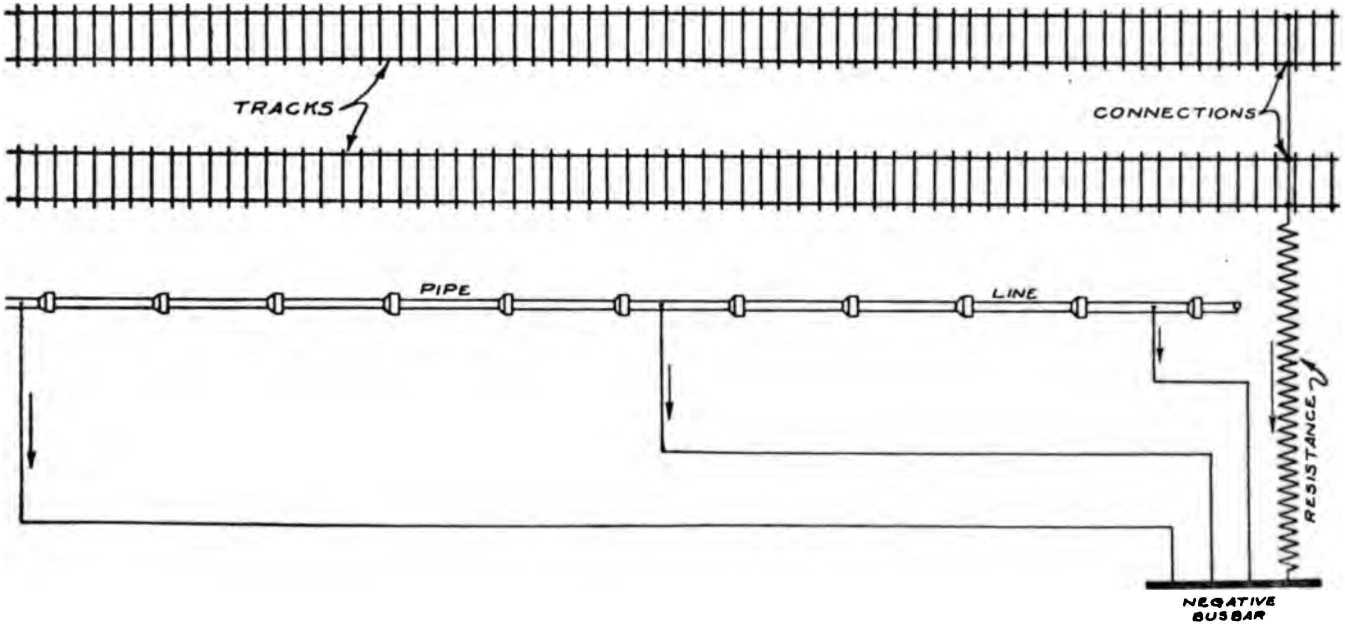


This plan is very easily adjusted electrically, but at the expense of loss of electrical energy through the interposed resistances to subsurface metallic structures and tracks.

FIGURE 3

(Diagramatical Plan)

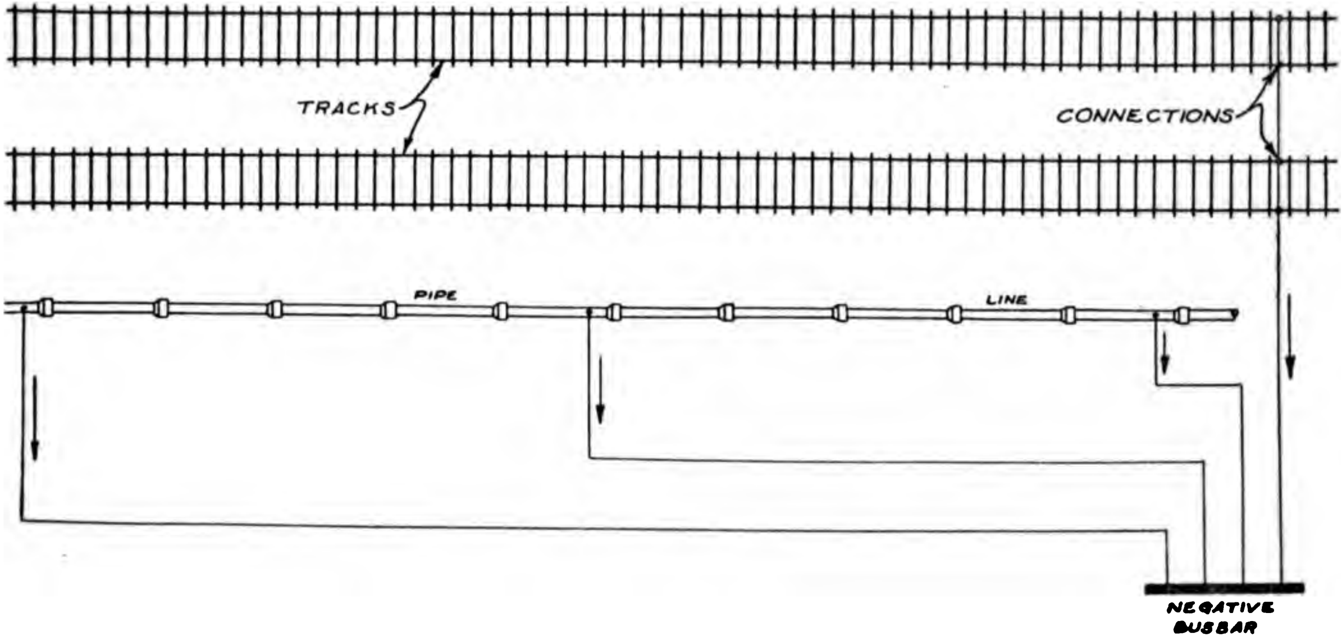
A practical Pipe Drainage System, consisting of connecting copper cables between the subsurface metallic structures and negative busbar, with additional electrical resistance in the track connection only.



This plan is very easily adjusted electrically, but at the expense of loss of electrical energy through the interposed electrical resistance in the track connection.

(Diagramatical [illegible])

The most efficient, practical and economical Pipe Drainage System, consisting of connecting copper cables between subsurface metallic structures and negative busbar, without any additional resistance.



This plan is not so easily adjusted electrically, but it has the advantage of the maximum available electrical carrying capacities of the copper cables from negative busbar to subsurface metallic structures and also to tracks. This plan is used more than any other electrolytic mitigating system in America.

FIGURE 5

(Diagramatical Plan)

A fairly practical plan of electrolytic mitigation, consisting of operating a Negative Booster Electrical Generator in conjunction with the Pipe Drainage System.

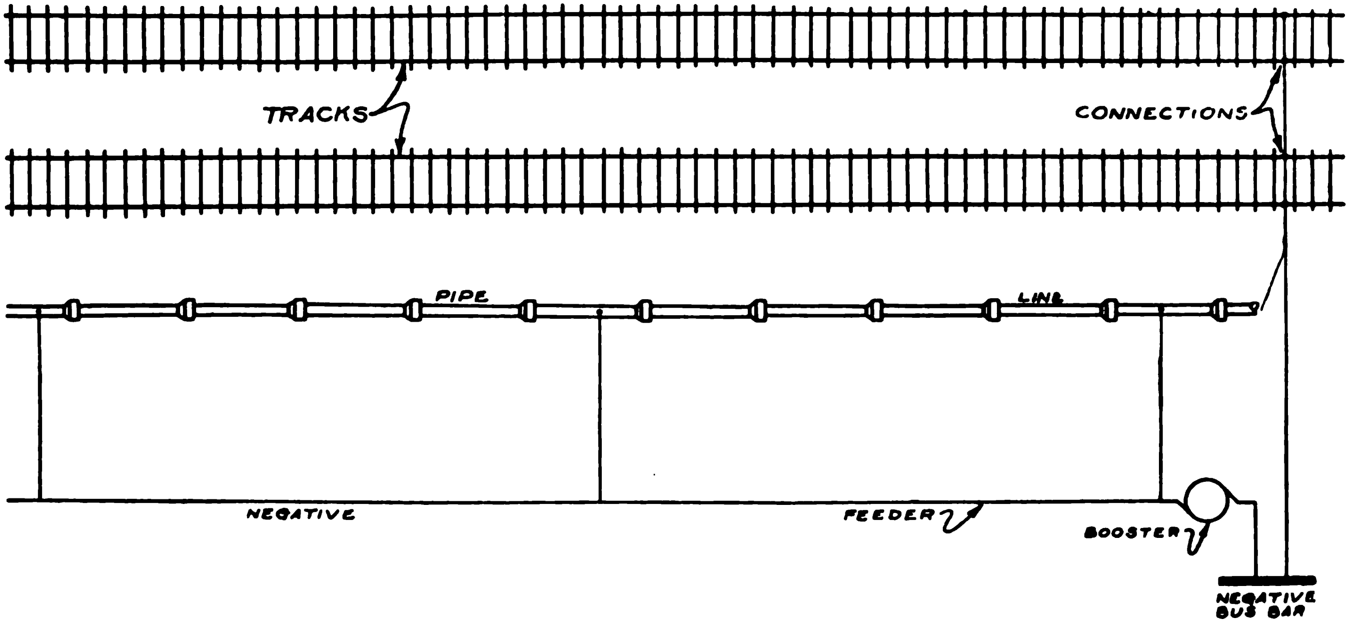
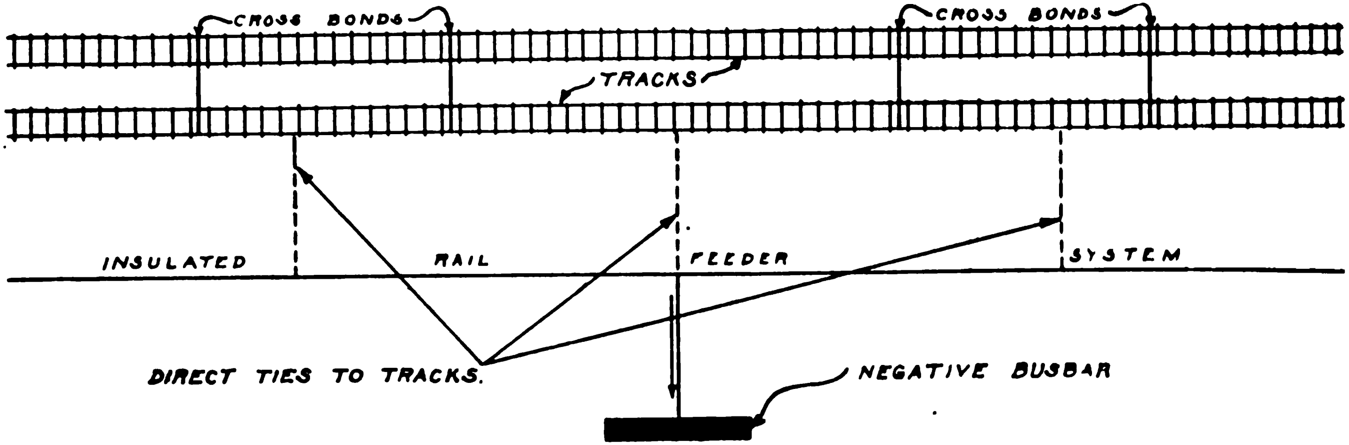


FIGURE 6

(Diagramatical Plan)

A simple Insulated Rail Return System, consisting of connecting copper cables between track system and the negative busbar.

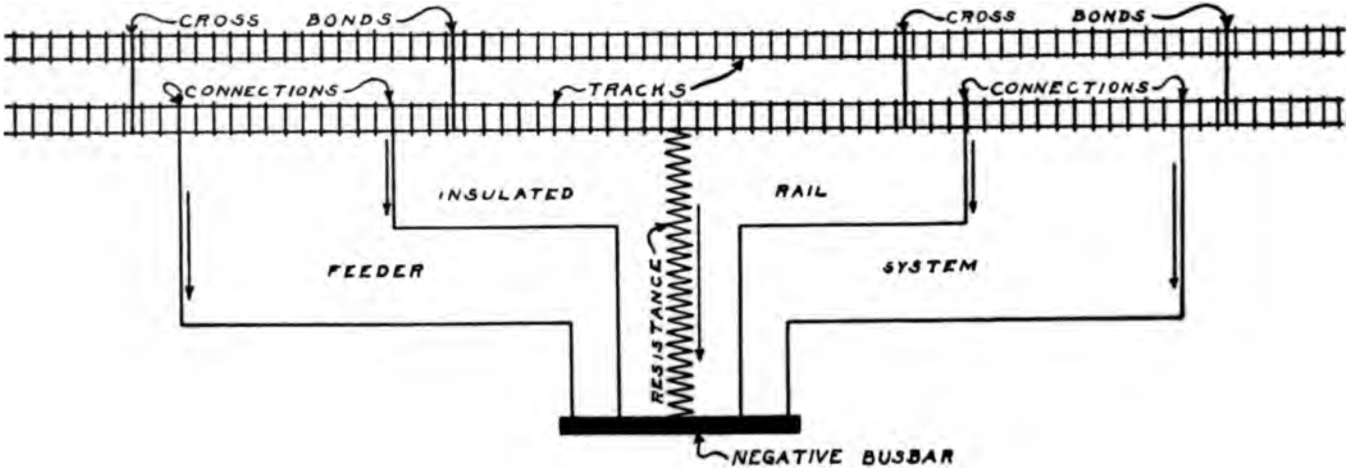


This plan of supplementary rail return feeders, has been in operation since the first electric street railway was started in America in 1888. It could therefore scarcely be called an electrolytic mitigating system. Its function is to electrically reinforce the track system.

FIGURE 7

(Diagramatical Plan)

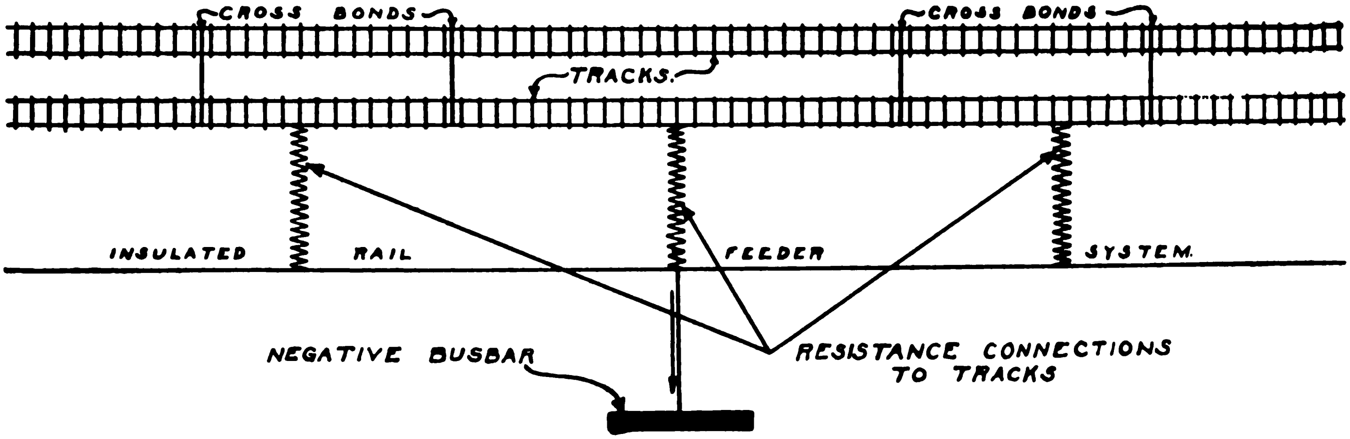
An Insulated Rail Return System, consisting of connecting copper cables between track system and the negative busbar, with additional electrical resistance in track tap nearest the negative busbar.



This plan of supplementary return feeders, has been used since the time of the first electric street car. The elctrical resistance in the track connection nearest the busbar is for the purpose of making the equi-potential losses from any track tap to the negative busbar practically the same. Advocated by the National Bureau of Standards, as an electrolytic mitigating system.

(Diagramatical Plan)

An Insulated Rail Return System, consisting of connecting copper cables between track system and negative busbar, through electrical resistance at each track tap.

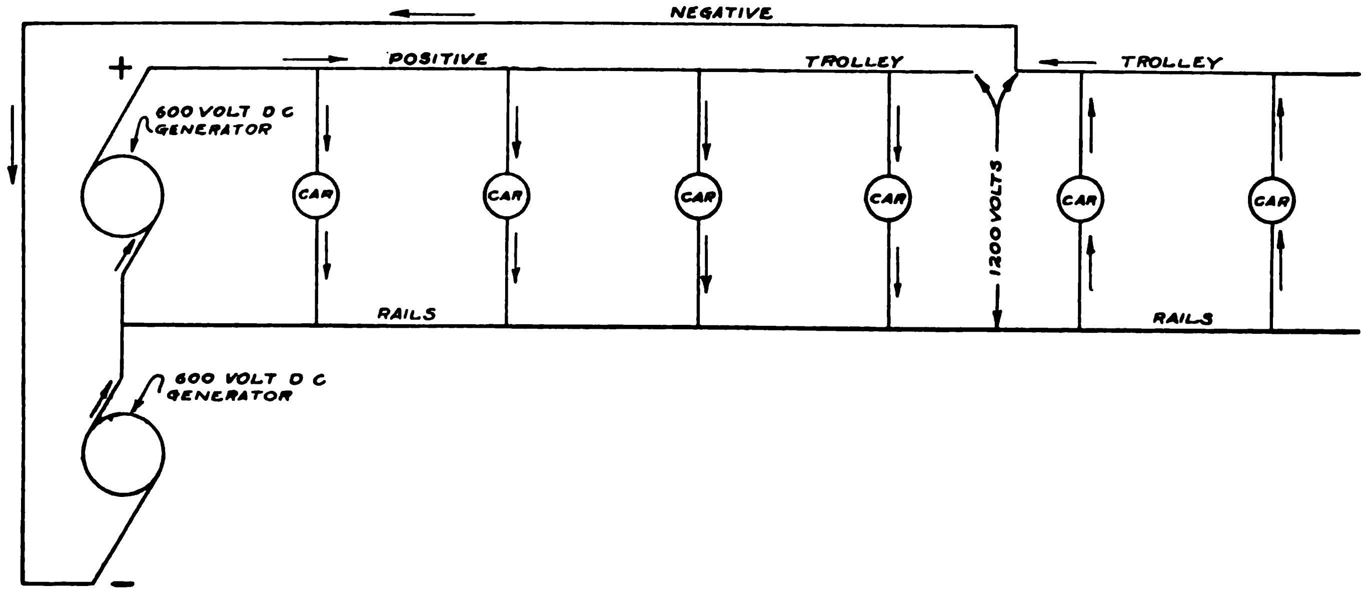

CROSS BONDS
CROSS BONDS
TRACKS.
INSULATED RAIL FEEDER SYSTEM.
NEGATIVE BUSBAR
RESISTANCE CONNECTIONS TO TRACKS

This plan, of supplementary return feeders, is an old one. The purpose of electrical resistance in each track connection is to maintain a uniform loss in electrical pressure from any track tap to negative busbar. The loss in electrical energy, without utilizing the maximum electrical carrying capacity of the supplementary cables and tracks, makes it in inefficient installation. Advocated by the National Bureau of Standards, and one of their favorite electrolytic mitigating systems.

FIGURE 9

(Diagramatical Plan)

A simple two-section Three-wire Trolley System, consisting of one trolley section electrically positive and one electrically negative to the neutral track construction.

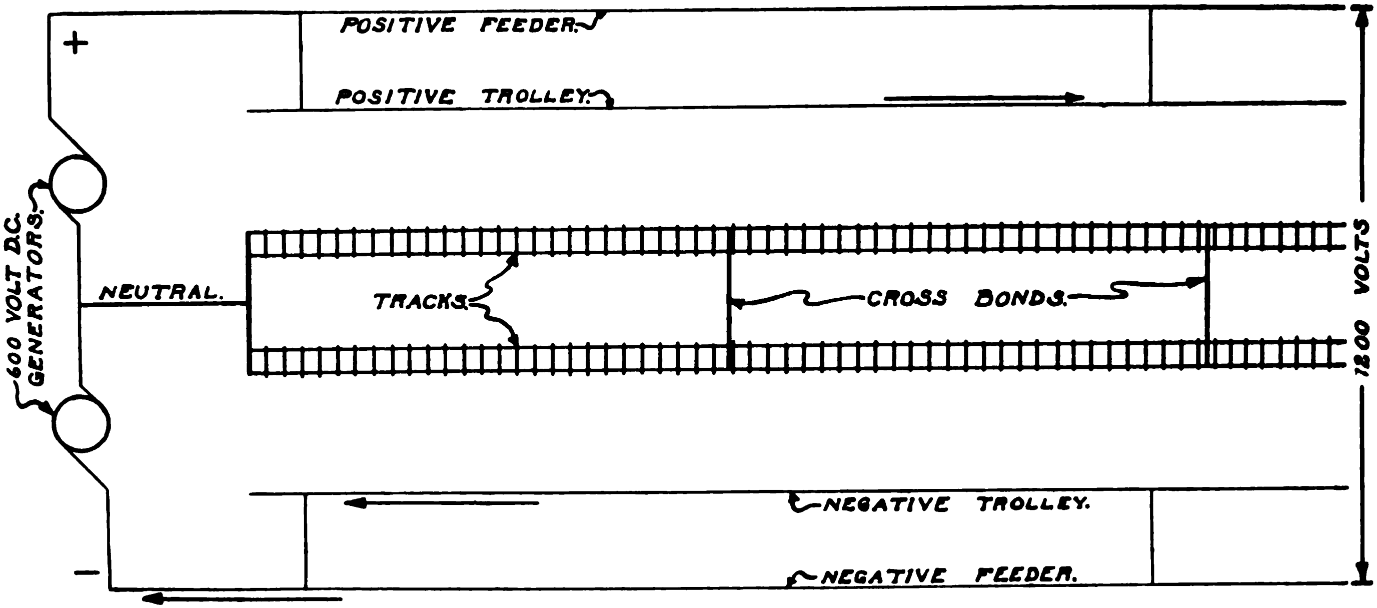


This principle is the latest advocated by the National Bureau of Standards, as an electrolytic mitigating system. The writer believes it to be impractical, uneconomical, inefficient, and dangerous to operate.

FIGURE 10

(Diagramatical Plan)

A simple two-section Three-wire Trolley System, consisting of one trolley wire electrically positive and the parallel one electrically negative to the neutral track construction.

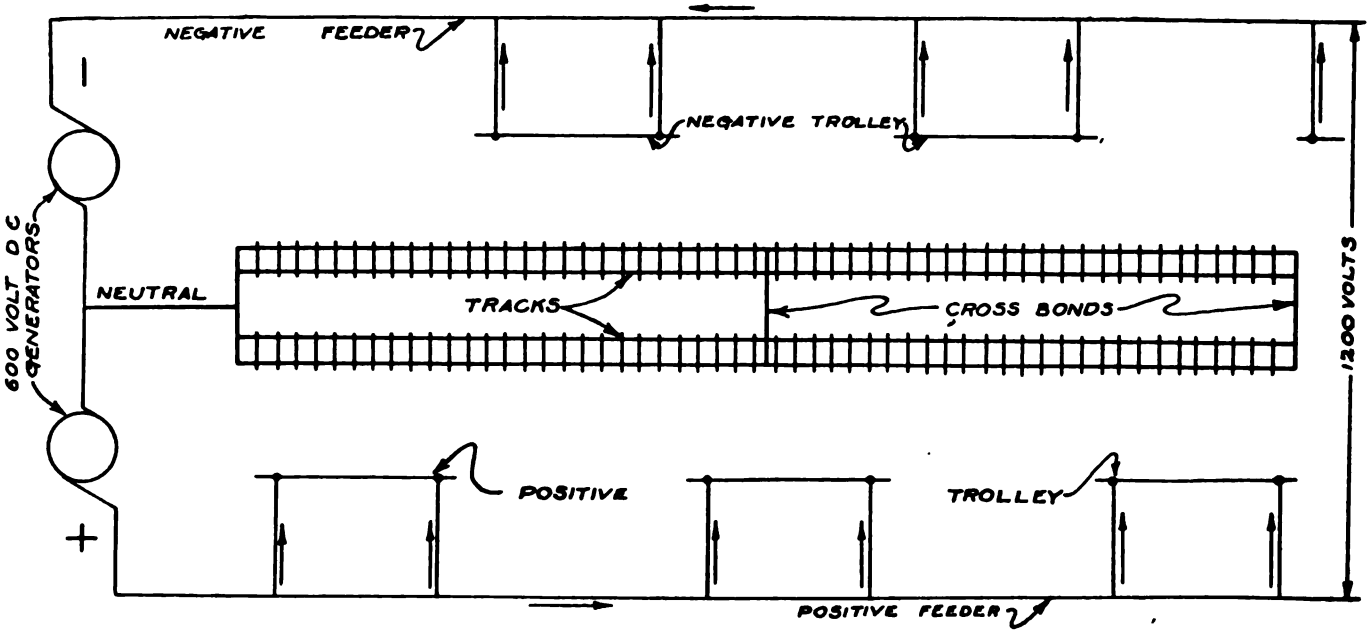


This is another application of the latest principle advocated by the National Bureau of Standards, as an electrolytic mitigating system. The writer believes it to be impractical, uneconomical, inefficient and dangerous to operate. It is being tried out in the City of Springfield, Massachusetts, and Milwaukee, Wis.

FIGURE 11

(Diagramatical Plan)

A multiple section Three-wire Trolley System, consisting of alternate trolley sections, one electrically positive and the consecutive one electrically negative to the neutral track construction.



PART X

THE WISCONSIN RAILROAD COMMISSION

Its Duties and the Extent of Its Jurisdiction

The Railroad Commission of Wisconsin was organized in 1905 to handle railroad service and rate matters. Subsequently thereto the word "railroad" was modified by statute to include street railways and interurbans, and the law was somewhat extended so that t included street railway and interurban practices, services and fares. About 1909 the public utility act was passed and the jurisdiction of he Railroad Commission was extended to public utilities. The word "public utility" in Wisconsin is defined by statute to include all telegraph, telephone, heating and lighting companies, power companies, as companies, and companies of a similar nature and the jurisdiction includes practices, services and rates.

THE WISCONSIN RAILROAD COMMISSION ON THE BELOIT, WISCONSIN, CASE

The writer has compiled the following data bearing upon the Beloit, Wisconsin, electrolysis situation. Beginning first with reiting the Wisconsin Railroad Commission's order upon this subject as follows:

BELOIT WATER, GAS AND ELECTRIC CO.

Vs.

BELOIT, DELAVAN LAKE AND JANESVILLE RAILW CO., BELOIT TRACTION CO., ROCKFORD AND INT URBAN RAILWAY CO.

Decided April 30, 1917

As regards electrolysis injury, the public requires that stree occupied both by electric railway systems and water and gas util The same general public patronize both classes of service and is tled, under regulation, to reasonably adequate service from ea reasonable rates. If railway systems, however, were so constr and operated that no electrolytic destruction was possible, patro the electric railway systems would undoubtedly be obliged to be unreasonable proportion of the total cost of maintaining the classes of business in the public streets. On the other hand, such conditions as at Beloit, destructive electrolytic corrosion excessive that an unreasonable burden is placed upon the gas water business, the seriousness of interrupting the services in tion because of corroded pipes being another factor entitled to consideration in such connection. The order in the present pro ing is intended to establish a condition which will bring abou maximum combined efficiency and reliability of all classes of se concerned.

The amount of dangerous current leaving the pipes where trolysis is taking place depends on several variables. These inc The amount of current used by the cars, the resistance of the bonds and wire in the return circuit, the size, position and resis of the pipe network, the electrical resistance between the pipe work and rails throughout the system and the electrical contac tween the rails and the earth.

Complaint that as a result of respondents' operation in the of Beloit a considerable amount of electrolytic injury, chiefly t gas service pipes and connections of petitioner, is taking place

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increasing rate; that petitioner has been obliged to take up and replace pipes that have been rendered unfit for service by reason of such electrolytic injury, and that such injury has increased until the situation is very serious and interferes with the service which petitioner renders to the public.

HELD: That destructive electrolytic action is taking place as alleged by petitioner; that both the local and the interurban traction systems are contributing to such destructive action by permitting an excessive amount of return current to flow through the earth and the underground pipes through failure to provide a full metallic return circuit of sufficiently low resistance, and that under present conditions the destructive electrolytic corrosion is so excessive that an unreasonable burden is being placed upon the gas and water business; that there are several methods of improving the electrolytic conditions in question, the choice of methods being properly a function of the electric railway companies, but that it appears that the corrosion involved will be sufficiently reduced without placing an unreasonable burden upon respondents if the electric railway systems are so constructed and operated that the average drop per 1,000 feet of rail taken for any period of fifteen minutes shall not exceed 0.5 of a volt.

Order in accordance with foregoing, all improvements necessary to comply with the order to be completed not later than September 1, 1917.

The petition in the above entitled matter was filed February 8, 1916. The petitioner alleges that subsequent to the construction and operation by it of a gas and water distribution system in the city of Beloit the respondents, with authority from the city of Beloit, built and operated electric railways within said city; that respondents' railways are provided with a single trolley and rail return; that in certain sections of the city the same track is used by both local and interurban railway companies, and that the energy used for operating all cars is received from the same source. The petitioner further states that a considerable amount of electrolytic injury, chiefly to the gas service pipes and connections of the petitioner, is taking place at an increasing rate; that petitioner has been obliged to take up and replace pipes that have been rendered unfit for service by reason of this electrolytic injury, and that this injury has increased until the situation is very serious and interferes with the service which the petitioner renders to the public.

Answers to the petition were filed by the resspondents to the

effect that they were within their legal rights and denying that
act or omission by respondents had resulted in damage to the
tioner.

A hearing was held at Madison on April 7, 1916. H. L. B
appeared for the petitioner, T. S. Nolan for the Beloit, Delavan
and Janesville Railway Company and the Rockford and Interu
Railway Company, and O. S. Baylies for the Beloit Traction C
pany.

The testimony shows that several surveys have been made
ing the last few years to determine the electrolytic condition
Beloit. The testimony and the reports of the surveys indicate a
material escape of electric current from the rails of the respond
to the pipes owned by the petitioner and a return of the current
the pipes to the earth and thence to the rails and negative sid
the circuit at the power station. It was also shown that a consi
able number of gas service pipes had been replaced because of
trolytic action.

At the hearing it was agreed that further data should be
lected by the engineers serving the Commission and a state
made of electrolytic conditions existing at Beloit without recom
dations regarding methods for remedying the situation. Subseq
to this hearing, the petitioner filed with the Commission a list o
pipes replaced because of electrolytic corrosion. The list sho
that the pipes replaced had been in service from two to twenty
years. Respondnts filed with the Commission data regarding tr
and bonds, including sizes and types, dates installed and simila
formation.

On July 27, 1916, the report of the engineers serving the C
mission was sent to the interested parties and a second hearing
after due notice, on August 9, 1916. The appearances at this h
ing were the same as those entered for the hearing on April 7.

From the testimony and the information collected by the en
eers serving the Commission and by the interested parties, it app
that destructive electrolytic action is taking place as alleged by
petitioner. Both the local and the interurban traction systems
contributing to the destructive action by permitting an exces
amount of return current to flow through the earth and the un
ground pipes because of failure to provide a full metallic return
cuit of sufficiently low resistance.

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ASTOR, LENOX
TILDEN FOUNDATIONS

The electrolytic action that destroys the gas and water pipes and other underground metallic structures varies in general with the amount of current leaving these pipes and entering the earth on its way back to the power station, and upon the length of time such current flows. Although at Beloit most of this corrosion takes place along the interurban tracks, a substantial part of the current causing this proceeding escapes to the pipes from the rails of the local company due to the high resistance of the return circuits of this company. The amount of dangerous current leaving the pipes depends on several variables. These include: The amount of current used by the cars, the resistance of the rails, bonds and wire in the return circuit, the size, position and resistance of the pipe network, the electrical resistance between the pipe network and rails throughout the system and the electrical contact between the rails and the earth.

The public requires that the streets be occupied by the electric railway systems and the water and gas utilities. The same general public patronizes both classes of service and is entitled, under regulation, to reasonably adequate service from each at reasonable rates. If the railway systems were so constructed and operated that no electrolytic destruction was possible, the patrons of the electric railway systems would undoubtedly be obliged to bear an unreasonable proportion of the total cost of maintaining these two classes of business in the public streets. Under the present conditions at Beloit, the destructive electrolytic corrosion is so excessive that an unreasonable burden is being placed upon the gas and water business.

The most satisfactory results are obtained when the total expense of replacing the corroded pipes and of returning the current from the street cars to the station is a minimum. Another factor which should be considered is the seriousness of interrupting the water or the gas service because of corroded pipes. It is the purpose of this order to establish a condition which will bring about the maximum combined efficiency and reliability of all classes of service concerned.

There are several methods of improving the electrolytic conditions found at Beloit, and the choice of methods is properly a function of the electric railway companies. The Commission will therefore confine itself in this proceeding to a specification of the electrolytic conditions permissible, as indicated by measurements and conditions that can be definitely specified and conveniently checked from time to time.

Considerable investigation has been carried on by the National

Bureau of Standards and various other investigators including c sulting and operating engineers representing both the railway pipe and cable owning utilities. There have also been several rat expensive experiments along this line, some railway companies h ing made costly changes in attempting to remedy electrolytic co tions only to find that the electrolytic action is less rapid in cert areas but that the area where destructive electrolytic action is t ing place has been increased to such an extent that the total rate destruction by electrolysis has not been materially reduced. It necessary that the respondents in this case determine the merits the various means which can be employed to remedy the situat and apply adequate means to bring about the required relief as sp fied in this order.

Since there are two railway companies concerned in this case is necessary for the Commission to specify a permissible drop in v age per 1,000 feet of rail rather than an allowable difference of pot tial between rails and pipes, in order that one rail way company m not be held responsible for defects in the return circuit of the ot company.

The drop in voltage along any section of rail is constantly cha ing throughout the period of operation and for this reason it is nec sary for us to specify further details in regard to measuring the av age drop per 1,000 feet. From a study of available remedies a requirements in force in other places carried on by the enginee covering the conditions at Beloit and elsewhere, it appears that structive electrolytic corrosion at Beloit will be sufficiently reduc without placing an unreasonable burden upon the respondents if t electric railway systems are so constructed and operated that t average drop per 1,000 feet of rail taken for any period of fifte minutes shall not exceed 0.5 of a volt. The drop in potential sho be measured over a length of track not less than 300 feet and t reading reduced to drop per 1,000 feet.

IT IS THEREFORE ORDERED, That the respondents, t Beloit, Delavan Lake and Janesville Railway Company, the Bel Traction Company and the Rockford and Interurban Railway Co pany, so maintain and operate their railway lines in the city of Bel that the average voltage drop for any 15-minutes period shall n exceed 0.5 of a volt per 1,000 feet when measured over a length rail not less than 300 feet.

All improvements necessary to comply with this order shall completed not later than September 1, 1917.

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ELECTROLYTIC SURVEYS AND REPORTS ON THE BELOIT, WISCONSIN, CASE

By E. E. Brownell

On August 21, 1917, the writer made an Electrolytic Survey in ie City of Beloit, Wisconsin. This survey was made for the bene- of the City of Milwaukee, Wisconsin.

The sole purpose in making the Beloit survey was to ascertain ' actual facts and personal knowledge, the original and unmitigated ectrolytic conditions upon the gas and water systems of the Beloit 'ater, Gas and Electric Company. These facts the writer ascer- ined for himself before any change was made in the physical or ectrical operation of (1) the Beloit, Delavan Lake and Janesville ilway Company, (2) The Beloit Traction Company and (3) the ckford and Interurban Railway Company. Although the case was cided by the Commission on April 30, 1917, no actual work had en done to carry out the order up to August 21, 1917.

The Rockford and Interurban Railway Company owns and oper- s a substation located in the southern portion of Beloit, Wis. One rt of the substation is in Wisconsin and the other in Illinois, the te Line passing through it. This substation is the only means of nishing the requisite electrical current to all of the above named ee (3) electric street railways in and through the City of Beloit. eoretically, this substation delivers electric current one-half the tance to Janesville, Wis., on the north, as there is another sub- tion in Janesville, Wis., and a powerhouse in Rockford, Ills.

The Electrolytic Chart facing page 210 of this report gives a aphic description of the unmitigated electrolytic conditions in loit, Wis., on August 21, 1917.

On April 20, 1919, the writer again visited the City of Beloit, is., and made another electrolytic survey of the water system. iring the interim between August 21, 1917, and April 20, 1919, the ctrolytic mitigating installation was finished.

The electrolytic conditions found in Beloit on April 20, 1919, are own upon the electrolytic chart facing page 212 of this report.

Therefore, the electrolytic conditions are shown both before and ter mitigation upon the two charts.

A third map showing the copper cables and the interposed electrical resistances of the electrolytic mitigation system will be found facing page 214 of this report.

COMMENTS

1. The installation of the Beloit electrolytic mitigating system was done under an order and under the supervision of the Railroad Commission of Wisconsin.

2. The engineer under whose direction the actual installation of the mitigating system was planned and constructed, is unknown to the writer, but it is very apparent that he had not the slightest idea of what he was doing, or the results he wished to accomplish.

3. His work was a woeful example of poor electrical engineering and a rank injustice to the electric street railway companies. It was, at the same time, of no benefit whatsoever, to the Beloit Water, Gas and Electric Company as a protective measure.

4. There is no doubt, in the writer's mind, that the Railroad Commission of Wisconsin thought it was advising the proper form of construction, but the engineering ability shown in this installation is without merit.

5. On looking over the charts, the reader will at once observe that the electrolytic conditions in Beloit were worse after the installation of the electrolytic mitigating system than they were before. The mitigating system has even increased the electrolytic menace upon the subsurface metallic structures.

6. The Railroad Commission of Wisconsin is not primarily to blame for this ridiculous installation. It was the fault of the parties behind them advising them to do that which is wrong in principle, that caused the Commission to be badly misled.

7. From all indications, it was an attempt by the Commission to carry out a general plan of the "Insulated Rail Return System" which the commission gathered from its direct association with the representatives of the National Bureau of Standards to be the proper method to pursue.

It is the fault of their advisors, as the Railroad Commission of the State of Wisconsin had every right to believe that the National Bureau of Standards had given them the proper technical advice on the subject. This is the real point.

8. The National Bureau of Standards, and probably Professor C. F. Burgess as well, knew perfectly well that the installation of the "Insulated Rail Return System," upon an interurban electric street railway line, is practically never effective in appreciably reducing electrolytic deterioration.

9. The electrical drops, or track gradients, south and north of Beloit, Wis., are naturally high, as they are on every interurban electric street railway system, and it is principally these conditions in the rural sections that produce the menacing electrolytic conditions in the City of Beloit. If the electric street railway lines did not extend outside the corporate limits of the City of Beloit, then there would be another story to tell; but they extend many miles with heavy track gradient, or high electrical track losses.

10. If all the copper in the whole State of Wisconsin was put in electrical parallel with the tracks, throughout the City of Beloit, the electrolytic conditions in Beloit would not be materially improved.

In other words, if the electrical loss along the tracks and copper feeders attached thereto was but one-thousandth (one millivolt) of a volt, there would still be serious menacing electrolytic conditions in the City of Beloit, for the main return current diversion is beyond the city limits of Beloit.

11. The Beloit situation is only another one where the technical principles of the National Bureau of Standards are not according to good sound electrical engineering practice.

12. This is a lesson for the Railroad Commission of Wisconsin and the City of Milwaukee, Wisconsin, not to follow blindly the teachings of theorists who have but limited practical knowledge of this subject.

Heaven pity the City of Milwaukee Water Works if the Railroad Commission of the State of Wisconsin carries out the plan of the National Bureau of Standards. The writer does not believe it will do this if properly advised.

PART XI

THE INTERURBAN STREET RAILW OF MILWAUKEE, WISCONSIN

CHICAGO, NORTH SHORE AND MILWAUKEE RAIL COMPANY

The Chicago, North Shore and Milwaukee Railroad Co was organized on June 1, 1916, under the laws of the State of

On July 26, 1916, it took over, at a foreclosure sale, the p of the Chicago and Milwaukee Electric Railway Company.

The Chicago and Milwaukee Electric Railway Compa given a franchise by the City of Milwaukee, passed on Febru 1906 (No. 158), to lay, construct and maintain an electric str way system.

On pages 16 and 17 of the Compilation Section of this rep be found the various sections of this ordinance.

The ordinance specifically mentions the operation of a head wire system, but leaves the other electrical features vague, as to construction.

The entire electric street railway system is a Single overhead line.

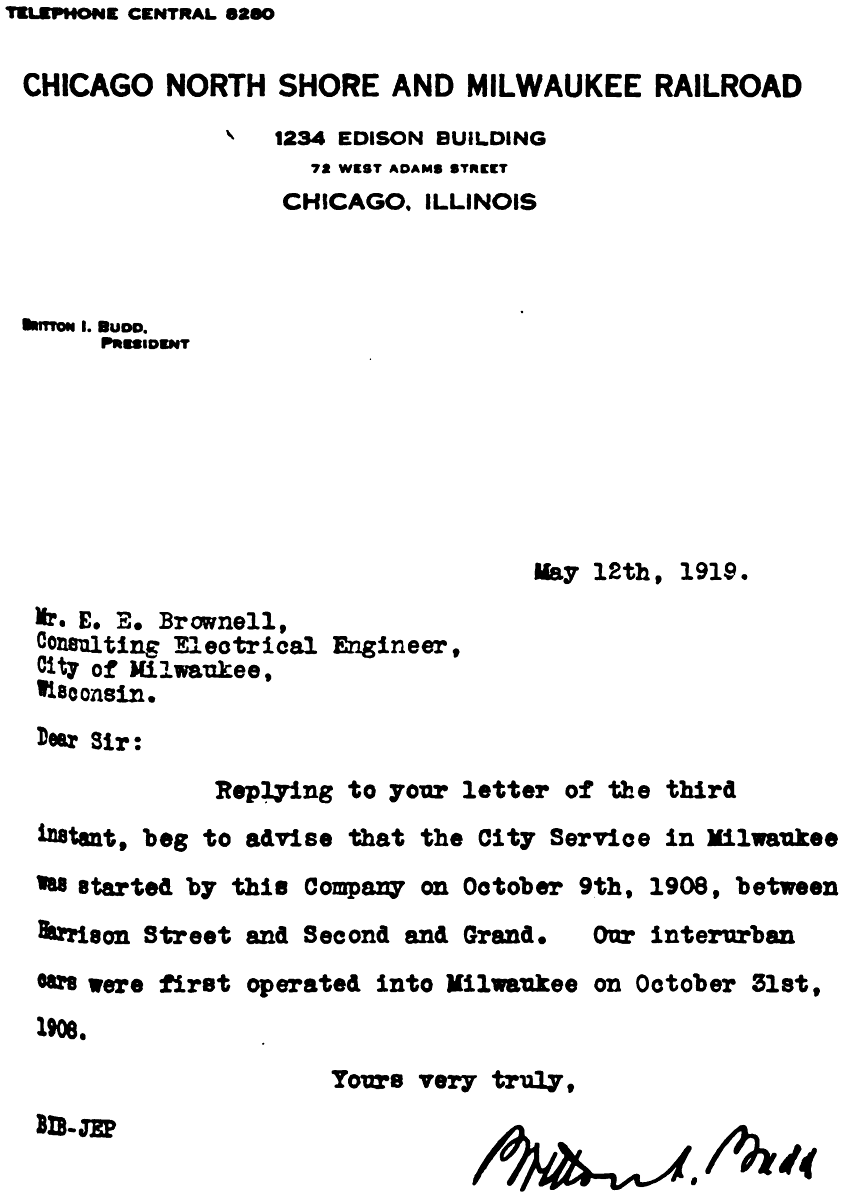
The company has a substation upon South Grove Street, furnishes electrical current to its system inside of the City waukee and also to a part of it outside of the city.

ELECTROLYTIC CONDITIONS

The Electrolytic survey made by the writer in April showed very serious electrolytic conditions along Grove Street electrolytic condition was quite local, but very acute, upon t waukee Water Works system.

At this time (1917) there were no metallic connections b the water pipe lines and the return circuit of the Chicago, Shore and Milwaukee Railroad Company.

The following letter is a fac simile of a letter from Mr. Br Budd, President, as to the original operation of this road:



TELEPHONE CENTRAL 8280

CHICAGO NORTH SHORE AND MILWAUKEE RAILROAD

1234 EDISON BUILDING
72 WEST ADAMS STREET
CHICAGO, ILLINOIS

BRITTON I. BUDD,
PRESIDENT

May 12th, 1919.

Mr. E. E. Brownell,
Consulting Electrical Engineer,
City of Milwaukee,
Wisconsin.

Dear Sir:

Replying to your letter of the third instant, beg to advise that the City Service in Milwaukee was started by this Company on October 9th, 1908, between Harrison Street and Second and Grand. Our interurban cars were first operated into Milwaukee on October 31st, 1908.

Yours very truly,

BIB-JEP

Britton I. Budd

MILWAUKEE NORTHERN RAILWAY COMPANY

The Milwaukee Northern Railway Company was chartered in 1905, under the laws of the State of Wisconsin.

On March 22, 1906, the City of Milwaukee passed an ordinance (No. 174) granting the Milwaukee Northern Railway Company the right to lay, construct and maintain an electric street railway system.

On pages 17 and 18 of the Compilation Section of this report will be found various sections of this ordinance.

It is not quite clear in this ordinance what character of system of electric street railway was contemplated, except that the electrical conductors were to be overhead wires.

This interurban electric street railway service began on October 28, 1907, and the local service, in the City of Milwaukee, on November 19, 1907. The entire system is a single trolley one.

The company has a substation located in Milwaukee, at the intersection of Atkinson and Green Bay Avenues and Sixth Street.

This substation feeds all of the system inside the City of Milwaukee and part of that which is outside of the city.

ELECTROLYTIC CONDITIONS

The Electrolytic Survey made by the writer in April, 1917, showed very serious electrolytic conditions along Atkinson Avenue and Sixth Street.

These electrolytic conditions were very local and acute upon the Milwaukee Water Works system.

At the time that this electrolytic survey was made (1917), there was in existence a metallic connection from the negative busbar, in the substation, to the water pipe adjacent.

Therefore, the Pipe Drainage System was in vogue with respect to the operation of this electric street railway company. How long it had been connected is unknown to the writer.

PART XII

LITIGATION ON ELECTROLYTIC DETERIORATION

PEORIA WATER WORKS COMPANY

vs.

CENTRAL RAILWAY COMPANY AND PROSPECT HEIGHTS RAILWAY COMPANY

On March 26, 1898, The Peoria Water Works Company filed suit against the Central Railway Company and the Prospect Heights Railway Company. By agreement between the parties, testimony was taken in Peoria, Ills., Chicago, Ills., Cincinnati, Ohio, New York, N. Y., Brooklyn, N. Y., Albany, N. Y., Philadelphia, Penna., Pittsburgh, Penna., Milwaukee, Wis., and Terre Haute, Ind.

On April 30, 1911, the Special Master in Chancery, Frank L. Wean, filed his report with the Court.

On May 13, 1912, the following decision was rendered:

IN THE DISTRICT COURT OF THE UNITED STATES

Northern District of Illinois
Eastern Division

Present: Honorable Arthur L. Sanborn, District Judge
Monday, May 13, 1912

Peoria Water Works Company

vs.

Peoria Railway Company, successor to
Central Railway Company.

No. 24,193

This cause having heretofore come on to be heard upon the pleadings, the evidence taken herein, the report of the special master of his findings of fact and conclusions of law filed April 13, 1901, and the exceptions of the defendant to said report, and also upon the report of said master under the re-reference for further testimony, wh report was filed June 22, 1909, and upon the exceptions of the defe ant thereto; and having been argued by counsel; and the court h ing found and decided that complainant's water works system been and is being damaged by electrolysis caused by electricity g erated by defendant, and that complainant cannot prevent such jury; that defendant shall take such measures, within a reasona time as to practically and substantially prevent further injury fr electrolysis, and that complainant co-operate with defendant to p vent or lessen the escape of electricity from the rails and from water pipes in such manner as to cause injury thereto.

1. It is thereupon adjudged and decreed as follows: The fendant Peoria Railway Company, and its officers, agents and vants, after one year from and after the date of this decree, are joined and restrained from injuring the water pipes, service pip hydrants and all other structures and property of complainant, Pe Water Works Company, through or by the escape of electric curr from the rails, or structures or property of the defendant.

2. It is further adjudged and decreed that complainant, Pe Water Works Company, its officers, agents and servants, shall p mit defendant, its officers, servants and agents, at their own exper at all reasonable times hereafter upon written request therefor, within a reasonable time after such request, to inspect its wa mains, service pipes and hydrants, in order to determine whether jury from electrolysis is being continued, the extent of the same, flow of the electric current upon the piping system and the ext thereof, and such other matters as may be necessary in order to termine whether defendant is complying with the terms of this dec

3. It is further adjudged and decreed that the findings of special master, so far as inconsistent with this decree, are overrul and in all other respects sustained and confirmed.

4. It is further adjudged and decreed that the Court reta jurisdiction of this cause for the purpose of enforcing by appropri orders herein, as occasion may arise, or in such manner as it m determine, the terms of this decree, and either party may at time apply to the Court for such further orders or directions in h mony with this decree as it may be advised is material.

5. Within six months after the expiration of one year after date of this decree defendant may in its discretion apply to the co

on notice to complainant, for a hearing on the question whether an order should be made for directing complainant to permit defendant to make experimental use of the "drainage system" so called, by connecting with copper wire the rails of defendant, or some designated portion of its rail system, with complainant's piping system, or some designated portion thereof, in order to ascertain whether such drainage system, or a limited use thereof, can practically be applied to said rail and piping systems.

6. It is further ordered, and adjudged and decreed that neither party have costs as against the other in the cause, and that each party shall pay one-half of the clerk's, marshal's, and master's fees and that the fees and expenses of witnesses, experts and engineers, and for examination and tests, shall be borne by the party calling the witness or requesting the service.

Dated May 13, 1912.

(Signed) A. L. SANBORN, Judge.

In the District Court of the United States of America for the Northern District of Illinois, Eastern Division.

I, T. C. MacMillan, Clerk of the District Court of the United States of America for the Northern District of Illinois, do hereby certify the above and foregoing to be a true and correct copy of an order made and entered in said Court on the thirteenth day of May, A. D. 1912, as fully as the same appears of record in my office.

In testimony whereof, I have hereunto set my hand and affixed the seal of said Court at my office in Chicago, in said District, this eighth day of June, A. D. 1912.

T. C. MacMillan, Clerk.

By John H. R. Jarnar, Deputy Clerk.

Upon reading the foregoing short decision, it will be readily observed that the Court deemed it very essential that co-operative measures be tried, as the first step toward the proper solution of the electrolysis problem in Peoria. Section Five places upon the Peoria Water Works Company, a privately owned public service corporation, the burden of showing why an order should not be given by the Court, compelling the adoption of the "Pipe Drainage System," or at least the experimental use of it for demonstrative purposes, so that its efficient electrolytic immunity might be practically ascertained.

For unknown reasons, the Peoria Water Works Company has never filed its answer. Now, after 14 years of expensive litigation with unlimited testimony, the case seems doomed to be discarded.

In the meantime, electrolytic conditions in Peoria, Ills., have gone unmitigated, without any one even taking a reasonable interest in the matter. This is another example of the effect of poor management, lack of organization, or unbusinesslike methods. There is now nothing to show for this great waste of time, money and effort. All because the Double Trolley System was to Mr. Maury the only practical solution by which this menace could be combated.

CITY OF DAYTON, OHIO, vs. THE CITY RAILWAY COMPANY

The first and original electrolytic survey was conducted on July 11-16, inclusive, 1898, by Harold P. Brown, electrical engineer, New York, N. Y., and E. E. Brownell, electrical engineer.

On November 15, 1899, the City of Dayton, Ohio, filed suit against The Oakwood Street Railway Company, The Peoples Railway Company and The City Railway Company, all of Dayton, Ohio. The case against The City Railway Company, No. 20763, was the one used as the test case.

On October 14, 1901, The City Railway Company filed its answer and on October 25, 1901, the City of Dayton replied.

On March 20, 1911, final entry was made disposing of the case, together with the cases against The Oakwood Street Railway Company and The Peoples Railway Company.

The basis of this injunction suit was an attempt, on the part of the City of Dayton, to compel the three (3) local electric street railway companies to adopt the "Double Trolley System" in place of the "Single Trolley System" then in operation. This was not, in the judgment of the writer, the proper course to pursue, and after being sworn into the case he resigned because of his disagreement with the plaintiff's attorneys and the electrical experts. The writer prophesied at that time (1901), that the City of Dayton would never be successful along this particular line of legal procedure, and lived to see the day (1911) when this was recognized as being the case.

The mutual understanding upon which this case was taken out of the jurisdiction of the Court, was that E. E. Brownell should act as Intermediary Consulting Electrical Engineer between the City of Dayton, and the six (6) local electric street railway companies and The Dayton Gas Company. Furthermore, that the "Pipe Drainage System" should be the plan of electrolytic mitigation and that installation of the Pipe Drainage System together with all additions, changes, modifications, etc., to it, should be paid for by the six (6) local electric street railway companies. These six (6) companies were also to pay for the professional services and expenses of the said E. E. Brownell.

Both the City of Dayton and The City Railway Company paid mighty dear for this lesson. However, without such legal action it is possible that no amicable working agreement and contract could ever have been properly consummated, to the satisfaction of all interested parties.

In 1911, there were nine sources of electrical grounded street railway currents within the corporate limits of the City of Dayton. This developed a series of complicated electrolytic conditions. Considering that there were also nine different electric street railway companies, it could not well have been made more intricate.

It would have been a physical impossibility to ever have equitably adjusted these conditions properly, except under the direct authority, control and supervision of one Consulting Electrical Engineer and Expert, or without legally executed agreements made between the City of Dayton and all the local and interurban electric street railway companies. In this adjustment the City of Dayton, the electric street railway companies and the said E. E. Brownell, all know the provisions of working agreements. There are no misinterpretations, nor is the consulting electrical engineer's responsibility divided with any other engineer.

This is the only plan that will ever bring to a successful conclusion the electrolytic evils in the City of Milwaukee.

Prof. Dugald C. Jackson, Dabney H. Maury, L. C. Anderson and others, are the only parties that ever realized any material profit out of this long drawn out litigation. Yet this suit cost the taxpayers of the City of Dayton, and also The City Railway Company, in either instance, a sum in excess of the amount requisite to have electrolytically mitigated these menacing conditions throughout the entire City of Dayton.

The City of Dayton from 1888 to 1911 or 23 years suffered irreparable electrolytic injury to the distributing cast-iron water works piping system and lead service pipes, amounting to tens of thousands of dollars, without receiving a cent for damages.

ELECTRIFICATION IN CITY OF DAYTON, OHIO

The White Line Street Railway Company began to operate its first electric car, as a single trolley system, on August 8, 1888.

The City Railway Company operating its first electric street car on April 7, 1890, from the Western Avenue powerhouse to the National Soldiers' Home, but did not operate upon the streets of the City of Dayton (electrically) until October, 1894.

Therefore, the latter road was only in operation four years before the original survey was made by Harold P. Brown and E. E. Brownell, or in July, 1898.

On account of political reasons, the White Line Street Railway Company (known as the Peoples Railway Company since August 1, 1896), which was in 1898 causing by far the greatest electrolytic damage to the Dayton Water Works System, was not made the defendant in this suit. The City Railway Company was made defendant in its stead.

It was chiefly through the efforts of Mr. Thomas E. Howell, General Superintendent of The City Railway Company, that by mutual agreement the case was taken out of the courts and amicably adjusted in March, 1911.

VILLAGE OF FRANKLIN, OHIO
vs.
THE SOUTHERN OHIO TRACTION COMPANY

Digest of Judge Clark's Charge to the Jury

In 1900, the Village of Franklin, Ohio, brought suit in the Common Pleas Court of Warren County, Ohio, against the Southern Ohio Traction Company, seeking to recover damages from the traction company for injuries sustained by the village to its water pipes by reason of electrolysis due to the defendant company's lines, and also to enjoin the defendant from continuing to inflict said injury.

In granting the franchise, the village council specifically required that the defendant's powerhouse should be located within the corporate limits of Franklin. The councilmen should have known, at that time, the injurious electrical condition which would result therefrom.

The damage case was tried by a jury in Judge Clark's court at Lebanon, Ohio, in March, 1901. In his charge to the jury Judge Clark held that because of the fact that the law conferred on the village council the power and made it its duty to direct the method of installing the traction company's lines, the installation of the single trolley system thereby virtually became the act of the village, and hence the plaintiff was estopped from recovering damages. At the same time he advised the jury that the village was not bound to suffer a continuance of the injury; that the then existing village council was not precluded by the action of its predecessors from taking such steps as would protect the village water pipes from further injury.

The jury, after considering the matter for two days, reported their inability to agree, and on April 2, 1901, were discharged.

The injunction case has never been passed on by the court.

There is no instance, everything else being equal, where a municipal water works piping system suffered so acute electrolytic deterioration, as in the Village of Franklin, Ohio.

THE INDIANAPOLIS ELECTROLYSIS CASE

SUPERIOR COURT, MARION COUNTY, INDIANA

Opinion Filed December 24, 1900

Manufacturers' Natural Gas Company

vs.

Indianapolis Street Railway Company

An electric street car company liable for injuring the pipes of a natural gas company by what is known as electrolysis.

(1) The plaintiff corporation owned in the streets of Indianapolis a pipe line for the purpose of transporting and furnishing natural gas for fuel and lights, and the defendant corporation owned and operated electric street cars upon the streets of said city by what is known as the Single Trolley System. HELD, that the defendant

was liable to the plaintiff for damages to its pipes caused by th action of electricity on said pipes, which electricity was discharge into the earth along the street by the defendant, in which operatio of its cars said action of electricity on said pipes being what is known as electrolysis.

(2) That the defendant by the use of approved appliances coul at a reasonable expense have prevented the injury to plaintiff's pipes and it was negligent in not so doing.

CARTER, J.

(Full recital of the demurrer omitted.)

For the foregoing reasons I think the complaint states a good cause of action, and the demurrer is overruled.

Note—This case practically never was carried any further by the plaintiff.—E. E. B.

DECISIONS IN THE SUPREME COURT OF OHIO

January Term, 1891

ELECTRIC RAILWAY vs. TELEPHONE

The Cincinnati Inclined Plane Railway Company,
Plaintiff in Error,
against
The City and Suburban Telegraph Association,
Defendant in Error.

Electric Street Railways—Single Trolley Overhead System—Rights of Telephone Companies

The order of the court will therefore be that the defendant be enjoined perpetually from the use of the system of electric railway propulsion as now operated by them, or any other which will occasion similar disturbances to those now caused by defendant's single trolley system. The order of injunction will not take effect until six months from this day, with leave to the defendant to apply to the court hereafter for further time, if necessary, in a bonafide effort to make the necessary changes. The costs of the action must be paid by the defendant. Decree accordingly.

It is the prevailing idea throughout the United States, that the above decision was rendered upon complaint of The City and Suburban Telegraph Association, and that it was caused by electrolytic deterioration to its physical property, or lead-sheath covered cables. This is not true. It was purely a case on conductive and inductive disturbances. The telephone company, in 1891, was also using one side of their circuit, as an earth return. No mention was ever made by either party as to electrolytic action, principally because there was nothing in Cincinnati, Ohio, which the telephone company then owned or used, that was susceptible to electrolytic corrosion. This was some years prior to the introduction of lead-sheath covered cables in Cincinnati, to the personal knowledge of the writer.

Today (1919), the question of conductive and inductive electrical disturbances in the City of Cincinnati is a dead one. Therefore, the permanent injunction applies to a condition that does not exist. The injunction, however, answers well for electrolytic protection, for which purpose it was never intended to apply.

It is a serious question in the minds of those legal experts associated with the writer, as to whether this perpetual injunction could not be dissolved, inasmuch as the reason for the injunction absolutely disappeared when the telephone company in Cincinnati, Ohio, installed their own metallic circuit subsequent to 1891.

The perpetual injunction would never have been granted, except for the fact that the grounded return currents of The Cincinnati Inclined Plane Railway Company invaded the private property of the telephone subscriber, debarring him from the lawful use of a privilege which he was enjoying, as between him and the telephone company.

The electric street railway company was powerless to prevent such electrical disturbances, so long as they continued to operate the Single Trolley System. Thus nothing was left for the Court to do, but issue a permanent injunction. No Court in the United States today would, for one moment, think of doing such a radical thing.

The Nashville, Tenn., and Albany, N. Y., Eau Claire, Wis., Akron, Ohio, Knoxville, Tenn., and Wilkes Barre, Penna., telephone cases were lost on these same grounds.

Mr. William Howard Taft, now ex-President of the United States of America, was the judge who issued the above decree.

The unsightly and expensively operated Double Trolley System in the City of Cincinnati, Ohio, is the result of unforeseen electrical development in construction of telephone plants. Had this interference been based upon an electrical condition, instead of upon an electrical construction, it would have automatically adjusted itself with the progress of the times.

Moral: Always specify electrolytic immune conditions to be met by the electric street railway companies, not the physical construction of an electric street railway return circuit. That is, **keep the pipe lines electrically negative to surrounding earth,** and then leave the expert electrical engineer, or authorized party, to work out this immune electrolytic condition in the best and cheapest manner.

COMPENSATION FOR ELECTROLYTIC DAMAGES

There is no record, in the courts of the United States today (1919), where any appreciable amount of damages has been awarded, either municipal or private, to the owners of subsurface metallic structures, because of electrolytic corrosion from the diverted return currents of electric street railways. These awards have been so small as to be negligible, amounting in most instances to from $10.00 to $100.00, and not over a dozen of these are on record. All of which were in the lower Courts.

The largest, and possibly the only municipality to receive from an electric street railway company, any considerable amount for electrolytic corrosion to its water works distributing system, was in Los Angeles, California. This is the first case where referees have settled a claim for electrolytic deterioration, between a municipality and an electric street railway company, and possibly the only one where more than one referee was appointed.

(From Municipal Journal, December, 1912, Page 841)

CITY RECEIVES CHECK FOR ELECTROLYSIS DAMAGE

> Los Angeles, Cal. By a check which City Attorney Shenk received from the Pacific Electric Railroad Company, Los Angeles is $42,500 better off than it was, and several thousands better off than it expected to be when it demanded damages from the electric company for injuring water mains through electrolysis. When the water department found mains in a number of streets destroyed by escaped electric fluid from Hollywood trolley lines a demand was made for $30,000. The railroad resisted payment and demanded adjudication by referees. These were named and after months of investigation they awarded the city $42,500.

The writer has, in many instances, been the sole referee in setements between gas, water and electric street railway companies; so between municipalities and electric street railway companies n questions of electrolytic damages to gas, water and lead-sheath overed cables, recovering up to the present time, by amicable adjustient, the sum of about $2,950,000. Most of these services were of a onfidential and professional nature.

The statute of limitation is the chief cause why no court of equity. n the United States of America, has awarded any appreciable claims or electrolytic depreciation. Unless the electrolytic conditions upon ny distributing gas or water system have been unusually well tested, t regular intervals, showing accompanying deterioration as following menacing electrolytic conditions, within the period of the statute of limitations, no engineer in the known world can prove his damage suit claim to even a reasonable degree of accuracy. It is beyond the possibility of man. That is why we have little or no records of court actions allowing claims for undisputed electrolytic deterioration upon gas, water and other subsurface metallic structures.

Attorneys always hesitate about bringing legal action against an electric street railway company because of progressive electrolytic corrosion, covering years beyond the statute of limitations, as set by the various State Courts.

If all the actual conditions were known, they would show that the aggregated electrolytic damage to gas and water systems, throughout the United States, was enormous. This is the writer's conclusion after twenty (20) odd years of exhaustive and practical field work.

Therefore: it behooves the owner of any subsurface metallic distributing system to make every reasonable effort to reduce to a minimum electrolytic deterioration upon these most valuable physical properties.

An immune electrolytic condition, not construction, should be agreed upon and every effort made to see that such a condition is insured through the services of an engineer properly and practically versed upon this subject.

A large number of claims have been paid by gas and water companies and by municipalities for damages done as a result of escaping gas and water from electrolyzed gas and water pipe lines. The courts hold these parties primarily responsible for the conveying of their commodities from the source to the consumer, no matter who or what may injure the common metallic carrier of these necessary public utilities enroute. The gas and water systems, however, must not be constructed in a careless or improper manner, so as to aggravate or make impossible the installation of reliable and known methods of electrolytic mitigation. These are very important phases of this subject.

PART XIII

AMERICAN TELEPHONE AND TELEGRAPH COMPANY COMMONLY KNOWN AS BELL TELEPHONE COMPANY OF UNITED STATES AND CANADA

As the Bell Telephone Company's interests in the United States have played such a prominent part in the Electrolysis question, beginning with the first electric railway system in Cleveland, Ohio, in 884, and continuing to date, it is deemed very necessary and appropriate to relate a brief history of the Bell Telephone Company, and its connection with the electrolysis question, covering briefly the conitions from various angles.

HISTORICAL

The American Telephone and Telegraph Company, the parent ompany of the Bell Telephone Company, was incorporated in New ork on March 3, 1885. The parent company operated the long disance telephone lines and the associated Bell Telephone Companies he exchange and toll lines, but under licenses from the parent comany.

The American Bell Telephone Company formerly owned all of he entire capital stock of the American Telephone and Telegraph ompany.

In March, 1900, The American Bell Telephone Company transerred all of its stocks and bonds to the American Telephone and elegraph Company, including its licenses, receiving from the Amerian Telephone and Telegraph Company two (2) shares of stock for ach share of The American Bell Telephone Company's stock, acquirng a total of $51,772,600 of American Telephone and Telegraph Comany stock.

In other words, the stockholders and bondholders of The Amerian Bell Telephone Company practically doubled the value of their oldings at that time. This value multiplied many more times, if eld for future sales.

In 1909, The American Telephone and Telegraph Company bought the $17,784,300 capital stock of the New York Telephone Company from other interests. Of this $17,784,300 New York Telephone Company stock, $16,221,880 was bought from the Western Union Telegraph Company.

In the year 1914, by reason of pressure brought to bear by the United States Government in 1913, and also on account of its apparently octopus position, the American Telephone and Telegraph Company was forced to sell its $29,657,200 stock in the Western Union Telegraph Company.

It further agreed, with the Department of Justice of the United States, not to acquire control over any additional independent telephone properties, except under specified conditions; and to give the independent companies toll rights over the long distance telephone lines of The American Telephone and Telegraph Company.

It was evident upon the face of it, that the chief object of The American Telephone and Telegraph Company, was to acquire, by fair or unfair means, all channels of telephonic and telegraphic communication in America. This they undoubtedly would have done, had not the United States Government stopped this apparent bold monopoly in 1913.

ELECTRICAL INTERFERENCE BETWEEN TELEPHONE COMPANIES USING A GROUNDED SYSTEM AND SINGLE TROLLEY ELECTRIC STREET RAILWAY COMPANIES

Beginning about the year of 1887, and ending about 1894, the various telephone companies throughout the United States sought to enjoin the adoption of the Single Trolley System, or any other electric street railway system of traction which employed the earth as part of its return circuit. The telephone companies laid claim to the prior uses and rights of the earth, and that it constituted part of their electrical system of circuits. Under such a claim they owned the earth.

There were at one time about 30 odd cases pending in the various courts throughout the East, South and Middle West. This was from about 1889-94.

Electrical disturbance was caused by conductive and inductive interference of conflicting grounded circuits, and NOT a single reference was made in any of these cases to "Electrolytic Deterioration."

The reason for this was that the telephone companies had little or no physical property that was subject to electrolytic action. Lead-sheath cables are the only part of an underground telephone system that could be deteriorated by the diverted electrical currents of a street railway company.

The references following will only be to the Single Trolley Systems, not overhead Double Trolley Systems, except where both constructions of pole line installations interfere with the various telephone companies.

There are seven different court cases, however, which were practically continued to a final adjudication on all electrical inductive and conductive interferences, as well as to the physical location of pole lines where the proximity was dangerous.

In the following citations, electrolytic action by electrical currents is not mentioned.

NASHVILLE, TENNESSEE

1. In 1879, the City of Nashville, Tennessee, gave the Cumberland Telephone and Telegraph Company the right to construct, operate and maintain a telegraph and telephone system. In 1888 the City of Nashville, Tenn., granted an ordinance extending the telephone plant as the public needs might require.

(a) On April 17, 1889, the Cumberland Telephone and Telegraph Company filed a bill in the Chancery Court in an attempt to stop the United Electric Railway Company from using any electric street railway system, using the earth, in part or as a whole, for the return of its electrical current, or that came in intimate electrical contact with the earth.

(b) At this time, April 17, 1889, the Cumberland Telephone and Telegraph Company had in use 1,400 telephones with 1,300 miles of wire throughout the City of Nashville, Tenn., all of which used a grounded telephone circuit.

(c) The United Electric Railway Company was then (1889) a consolidation of the five street railway companies, furnishing transportation for 15,000 persons per day. The Act granting them the right to electrify the horse car lines of Nashville, Tenn., was passed on March 21, 1887, by the Tennessee Legislature, providing, however, that the City of Nashville, Tenn., gave its assent. This Act was amended on February 28, 1889.

(d) At this time (1889) the cities of Montgomery, Ala., Pittsburg, Penna., Albany, N. Y., Appleton, Wis., Denver, Colo., Mansfield, Ohio, Asbury Park, N. J., two lines in the City of Cincinnati, Ohio, and others were operating the Double Trolley System which, furthermore, was installed by the free will and accord of the electric street railway companies. No legal action or municipal pressure, whatsoever, was brought to bear upon the double trolley companies, at this time.

(e) In the various legal actions taken by the telephone companies, it was admitted that of the four systems of electric traction then in use (and known in 1889 as the Storage Battery System, Conduit System, Double Trolley System and Single Trolley System) the single trolley system was the most practical and the least expensive to operate.

It was soon determined that, from an investment and operative standpoint, the single trolley system had a decided advantage over any other system of electric street railway construction, operation and maintenance. With a few metallic connections to water pipe lines, the single trolley **could** possibly operate without any regard, whatsoever, to the electrical construction of its rail-return circuit, as none was needed for this purpose.

(f) The Cumberland Telephone and Telegraph Company endeavored by injunction proceedings to have the courts force the United Electric Railway Company to adopt the Double Trolley System instead of the single trolley system. To have done this would have cost the United Electric Railway Company a sum not less than $150,000, while the Cumberland Telephone and Telegraph Company could have equipped the whole telephone system of Nashville with complete metallic circuits of their own for a sum less than $4,000. This was another example of the selfish methods and narrow views of telephone companies.

(g) The final disposition of this case was not made until March 11, 1894, or about five (5) years after the filing of the bill. The Cumberland Telephone and Telegraph Company was allowed the sum of $3,660.58 for changing its circuits to metallic lines, known as the McCluer (C. E. McCluer invention) Device. The telephone company further received, from the United Electric Railway Company, the sum of $816.00 for changing some of its poles which change was made necessary by the close proximity of the trolley and positive feeder wires of the electric street railway system.

Much divided court opinion prevailed in this case.

ALBANY, NEW YORK

2. In the case of the Hudson River Telephone Company vs. Watervliet Turnpike and Railroad Company, the Court of Ap- s of the State of New York reversed the decision of the Supreme rt of the State of New York. Briefly stated, the Court held , the telephone company's use of the street, being a subordinate , it could not complain of injuries inflicted or interference sus- ed, when at the same time, it possessed economically and prac- lly an inexpensive method of its own, which could be applied iout working an undue hardship upon the telephone company. s case was decided in October, 1892.

CHATTANOOGA, TENNESSEE

3. In 1889, The East Tennessee Telephone Company filed a suit inst The Chattanooga Electric Street Railway Company, in an rt to get a restraining order from the Court to compel the street way company to adopt the Double Trolley system instead of the posed single trolley system of electric traction. This was before electric street railway began operating in the City of Chattanooga, inessee.

The Court refused to grant an injunction, therefore the single ley system was built in Chattanooga, Tenn.

The case was decided in the Chancery Court of Chattanooga, inessee, on June 21, 1889.

KNOXVILLE, TENNESSEE

4. In 1890, The East Tennessee Telephone Company brought action against the Knoxville Street Railroad Company, for the pose of getting the court to enjoin it from using the Single Trol- System, or any system of electric traction which used the earth its return circuit. In April, 1890, this case was decided in the incery Court of Knoxville, Tennessee. The Court held, that the phone is NOT the proper use of the street, but that the electric et railway is the proper use, and that it could not be enjoined r such right had been given by the City of Knoxville.

EAU CLAIRE, WISCONSIN

5. On January 29, 1890, the Wisconsin Telephone Company and Eau Claire Street Railway and The Sprague Electric and Motor npany case was decided by the Wisconsin Supreme Court.

This case was very unique, as follows: The Wisconsin T phone Company brought suit against the Eau Claire Street Rail and The Sprague Electric and Motor Company to enjoin them f operating a "Single Trolley Electric Street Railway System" (a being in operation three months) in the City of Eau Claire, W consin.

The Wisconsin Telephone Company was, at that time, us a grounded telephone system, and, claiming again the exclusive rig of the earth, tried to keep the electric street railway company fr doing so.

The Court decided that as both the electric street railway co pany and the telephone company were violating the provisions Chapter 375 of the laws of the State of Wisconsin, that an inju tion could not be granted on these grounds. Briefly, it was one s ner endeavoring to bring legal action against another sinner on lawful grounds. This was the greatest joke of all the various te phone companies litigation on electrical interference.

Note—This accounts for the great haste made by the Wisc sin Telephone Company, in the City of Milwaukee, Wis., in 18 to abandon a grounded telephone system. It was because they w so compelled.

(See pages 32 and 33 of the Compilation Section of this rep for Chapter 375 of the laws of the State of Wisconsin.)

This decision is reprinted on pages 77-80 of this report.

AKRON, OHIO

6. In 1888, The Central Union Telephone Company filed s against The Sprague Electric Railway and Motor Company and T Akron Street Railway Company in an attempt to debar them fr the use of the grounded electric street railway system.

In January, 1889, the Common Pleas Court of Summit Count Ohio, decided in favor of the electric street railway company on t grounds that the telephone did not have exclusive right to the ear and that the telephone company should protect its own ground system.

WILKES BARRE, PENNSYLVANIA

7. As late as on February 8, 1892, the Common Pleas Court

Luzerne County, Pennsylvania, decided a case similar to all of the foregoing six cases. This case was Central Pennsylvania Telephone and Supply Company vs. Wilkes Barre and West Side Railway Company. The street railway company winning the suit, as usual, except for that in Cincinnati, Ohio.

CINCINNATI, OHIO

In the case of the City and Suburban Telegraph Company vs. The Cincinnati Inclined Plane Railway Company, decided in the Supreme Court of Ohio, June 2, 1891, the telephone company was granted a perpetual injunction against the railway company, and as a direct result, the City of Cincinnati, Ohio, has the overhead Double Trolley System.

(a) Many millions of dollars have been spent in the City of Cincinnati, for additional construction of the Double Trolley System. Its intricate overhead line construction and expensive maintenance and operation, together with the increased hazard to its employes, dangers from fire risks and to city firemen, all combine to make it an unsatisfactory system.

(b) All of this expenditure, covering many years of operation, would have been unnecessary, had the City and Suburban Telegraph Company installed a metallic circuit on its own telephone system, the cost of which would at that time, not have exceeded the sum of $30,000. Yet instead of this the electric street railways were compelled to expend millions, besides the interest on the investment and the resultant inferior operation of the road.

(c) The ridiculous feature of this whole case, is that this telephone company, a few years following this court decision, installed a complete metallic circuit system, at their own cost and expense, and of their own volition, in order to provide the requisite service.

(d) Therefore, there has existed for many years past, no real necessity for such a perpetual injunction, and it is today a question among the leading legal talent, as to whether or not this court order is not null and void, since no necessity for its continuance prevails.

(e) From the electrolytic standpoint, it was very fortunate for the owners and operators of subsurface structures in Cincinnati, Ohio, that such immune electrolytic conditions have prevailed for so many years, but certainly no credit for this is due The City and Suburban Telegraph Company, and its successors, the American Telephone and Telegraph Company.

WISCONSIN TELEPHONE COMPANY OF MILWAUKEE, WISCONSIN

While the writer was searching the various New York, N. Y., libraries, he ran across the following article, which is of considerable historical benefit:

METALLIC CIRCUITS WISCONSIN TELEPHONE COMPANY, MILWAUKEE, WISCONSIN

ELECTRICAL REVIEW

ILLUSTRATED.

A·WEEKLY·JOURNAL·OF

Electric Light, Power, Telephone, Telegraph and Scientific Progress.

VOL 19, No 17. WEEKLY NEW YORK. SATURDAY DECEMBER 19, 1891 $3 per Annum. Single Copies, 10 Cents.

THE MILWAUKEE TELEPHONE SYSTEM

Within a short time the telephone exchange at Milwaukee, Wis., will have a new home. The circuits are to be made metallic and the system otherwise improved.

A year ago two pair of wires were strung as far as Waukesha under these conditions, and they have been extended to Appleton giving the people up there direct connection with the long-distance line to Chicago. Racine and Milwaukee are also connected by the same system. By the use of the modern switchboard, Appleton and Chicago can be connected as quickly as a connection can be made between two points in the same town.

About $400,000 has already been expended in subway work. The subways built in 1889 contain 875 miles of wire. The underground work now in progress will bury about 2,056 miles, including submarine cables. This will make a total of 2,931 miles of new copper wire in the subways. Of these about 2,000 miles will be actively employed, the balance having been placed there to accommodate future growth. These figures do not include the aerial wires used for connections.

The work of connecting all these wires with the new $40,000 switchboard is no small job, as it required he labor of 20 men for 60 days in making 120,000 solid connections between the cable heads and the subscribers' spring jacks on the switchboard. The switchboard, as at present arranged, has a capacity for 2,400 subscribers, with an ultimate capacity of 4,000.

The connection between the subway cables and the switchboard requires 264 miles of wire, with 47 soldered connections for each subscriber's line.

The average cost for installing each subscriber into the new metallic circuit exchange will represent an actual outlay to the company of $167. This includes the wire and terminal facilities necessary to furnish metallic circuit service. If dead capital were reckoned in the calculation, the cost would be $185 for each subscriber.

The Wisconsin Telephone Company extends its wires into what are called 40 radii, each within 15 miles of an exchange. There are in the State 80 exchanges and 190 toll stations. Besides these, the company has 350 contracts for private lines and speaking tubes, not in connection with exchanges.

There are 6,300 miles of wire in the air within the limits of thc exchanges, besides 2,700 miles of toll line in addition, carrying 3,500 miles of wire operated on the ground circuit system.

There are 410 persons of all classes employed by the company to attend to the wants of 6,820 subscribers. Of this number 2,450 reside in Milwaukee, and 3,370 in the rest of the State. The toll messages transmitted annually run up to 176,000 in number.

The building which the Wisconsin Telephone Company has erected on Broadway is a model for the two purposes for which it was put up. The first consideration was to erect a central office that would be as near fireproof as possible.

The second consideration in erecting a permanent home for the exchange was to make it as comfortable as possible for the officers and employes who were to inhabit it. This work has also been performed as successfully as was the labor of getting up a building that would not burn. The building represents an outlay of between $75,000 and $80,000 and it is constructed so as to guard against both exterior and interior fires. It is five stories high, with a terra cotta front that presents a neat and novel appearance.

The basement of the building is used for the reception of the cables, which are properly arranged and numbered, and are so plac that one can be taken out without disturbing the rest. There is roo in the basement for 72 cables, not over half of which number is need at present.

The conduits which the Telephone Company puts in for its unde ground system are made of vitrified clay, ten inches square, with shelf in the center, thus dividing them into two chambers.

They have a carrying capacity of six cables, and will thus accommodate between 500 and 600 subscribers on each line of conduit. The are buried two feet underground and have a manhole at the end c each block.

Near this manhole a pole stands carrying a pipe in which ar the wires which connect subscribers in the immediate neighborhoo

Current is furnished to the exchange from a storage batter plant.

The officers of the Wisconsin Telephone Company are: Henr C. Payne, president; C H. Haskins, vice-president; John D. McLeo secretary; F. G. Bigelow, treasurer; Frank E. Parker, superintenden E. B. Cotterill, auditor.

It is self-evident, from the above article, that the Wisconsi Telephone Company began to place its wires (downtown distric underground, in the City of Milwaukee, Wis., a few months prior t the date (October 14, 1889) on which the Milwaukee City Railroa Company, Cream City Railroad Company and the West Side Rai road Company were given authority, by the Common Council of th City of Milwaukee, Wis., to change their motive power to electri traction, and that the reconstruction periods of both public utiliti ran together for a few years' time.

In any event, there are no available records, which would ten to show any objections, on the part of the Wisconsin Telephon Company, to the use of the Single Trolley System in the City of Milwaukee, either before or at any time after its installation and operation, which began on April 4, 1890.

POLICY OF THE BELL TELEPHONE COMPANIES ON ELECTROLYTIC MITIGATION

Mr. Isaiah H. Farnham, chief engineer (1889-94), New Englan

Telephone Company, Boston, Massachusetts, was the first engineer, of any note, in the United States, to adopt an electrolytic mitigation system.

He recommended and installed the "Pipe Drainage System" for the lead-sheath covered cables of the New England Telephone Company in 1892, as a means of protecting them from electrolytic corrosion resulting from the operation of the West End Street Railway Company, Boston, Mass.

The following article will give considerable light upon the early method of electrolytic mitigation, at Cambridge, Massachusetts.

CAMBRIDGE, MASSACHUSETTS

(The Engineering Record, March 18, 1893, Page 319)

The action of the trolley system on underground metallic work was first called to the notice of Charles H. Morse, Superintendent of Wires of Cambridge, Mass., by a complaint from the New England Telephone Company during the spring of 1892. The telephone company claimed that the metallic covering of their cables was being destroyed by something, which they believed was the action of the ground current of electricity from the trolley wires. The cables vary in size, those in use in Cambridge being about 1½ inches in diameter, and contain a large number of insulated telephone wires. Each cable is drawn into a lead pipe. This pipe in turn is drawn into a wrought-iron pipe. Some 20 or more of these pipes are placed in a wooden conduit, spaces being left between the pipes which are filled with concrete. The top of this conduit is about 2 feet below the surface of the street. It will be readily understood that the construction of one of these conduits involves the expenditure of a large sum of money, and anything endangering its permanence is a serious menace to the telephone company. When the electrician of the telephone company first had his attention drawn to the fact that the cables were being in some manner affected, it was thought that the trouble might be due to the action of the acid used in preserving the wood of which the conduits were constructed. But a simple experiment seemed to fasten the responsibility on the trolley system.

A voltmeter was connected with one of the cables in use, and the voltage of the current on the cable ascertained. Two pieces of new cable were then inserted in a barrel of moist earth, the conditions, as nearly as possible, being the same as those pertaining to the cables in use. Wires were than attached to one piece, and a current of the same voltage as that found in the ground was passed over it. In two weeks the piece of cable so connected was badly pitted, while the other remained perfect. It was suggested that the railroad company substitute for the copper wires under the rails some of a much larger size. The suggestion was adopted. In Cambridge, wires of about five-eighths inch diameter were employed, while in Boston the whole distance covered by the conduits was protected by a wire nearly an inch in diameter.

The other method (of electric propulsion), and that now employed by the West End Railroad Company, is the reverse of that just mentioned, the current in this case leaving the station by an overhead wire, thence through the trolley wheel and lever to the motor; then to the underground conductor and back to the station. Now, under certain conditions, the current, in its endeavors to return to the power station, is liable to leave its proper road, and run "across lots" by any bypaths that may present themselves. The paths most easy of access are, of course, the gas and water pipes, and these the current appropriates to its purposes without regard to consequences. Now, if I understand the matter correctly, the action on the pipes which ensues is very similar to that in an ordinary cell of a voltaic battery. Any one who has been unfortunate enough to have the care of many of these cells must be aware that in the zinc or negative pole a constant wearing away is taking place, necessitating frequent renewals. So with the pipes over which the trolley current happens to pass. No damage results where the current passes on to the pipes; when it leaves them, however, serious results may follow. Perhaps I ought to say that the wires have suffered at times in common with the pipes, but as we are not especially interested in that direction we will let that pass.

During the autumn of last year many reports of leaking supply pipes were received at the Water Office. But as most of them came from a district where the soil was not such as would be conducive to longevity in the pipes, nothing for a time was thought of it. But as the reports became more frequent, the Superintendent became convinced that some influence other than the ordinary oxidation was affecting the pipes. The Water Board requested Mr. Morse to investigate the matter, and in a series of experiments he found currents of electricity flowing over the gas and water pipes in all parts of the city, though more particularly near the power station, the district where the supply pipes had been most acted upon. The trouble inased; some of the pipes were renewed; galvanized, tar-coated, d "rustless" pipe being each tried in turn, but all were about equally ected.

In some cases new pipes were destroyed in a month's time. Not ne was the trouble confined to the supply pipes. In laying a -inch main the packing yarn, while being driven took fire. The int maker received some severe shocks, and was obliged to drive s yarn with wood. In a building located on a corner, two water pplies were connected by a copper wire. Sufficient current was ssing over the wire to heat it too hot to be held in the hand.

Mr. Morse requested the railroad company to connect the mains frequent intervals with copper wires, more especially at the "dead ds" of the pipes. For a time it was thought this remedy might re- lt in "robbing Peter to pay Paul," or, in other words, while the hange would prove beneficial to the water pipes, it would throw an dditional burden on the gas pipes. Mr. Morse therefore suggested at the gas and water supply pipes be connected by stout copper ires at numerous localities over the city, hoping that this plan might medy the evil. The railroad company expressed a willingness to omply with the suggestion and were preparing to do so. Recent sts, however, led Mr. Morse to think inasmuch as the gas mains re connected by cement joints, that these may prove a source of pro- ction, and that connecting the supplies might result in harm rather an good.

In a word, the whole question is of such recent origin and pre- nts so many different phases that it seems to me the problem is far om being solved. I mentioned that up to date but one instance had me to our notice where the action of the electric current could be early connected with damage to our pipes. This pipe was a 1¼ ch galvanized pipe. After leaving the main it passed under the lephone conduit, then across the street, under two tracks. It was tween these tracks that the break occurred. The pipe remained rfectly sound, except at each side of the coupling where it was eaten rough.

CHICAGO, ILLINOIS

From Report Made Peoples' Gas Light and Coke Company, Dated December 21, 1912

In this special report, made to Mr. E. G. Cowdery, Vice-President, oples Gas Light and Coke Company, by Messrs. Dugald C. Jackson, Dr. E. B. Rosa (National Bureau of Standards) and H. S. V ren, electrical engineer, American Telephone and Telegraph Comp pages 21 to 27 inclusive, the use of the "Pipe Drainage System" severely discouraged for the City of Chicago, Ills., for use by the Gas Company.

On page 58 of this report (December 21, 1912) Mr. H. S. Wa admits, that an elaborate and extensive "Pipe Drainage System" been installed and maintained for many years on the lead-sh covered cables of the Chicago Telephone Company. This, to personal knowledge of the writer, caused serious electrolytic co tions upon other subsurface metallic structures, as far back as year 1901.

Wherever, in the various cities in the United States, the Telephone Company's interests have lead-sheath covered cables conduits, and there are single trolley electric street railways, or e tric railway systems using grounded circuits, it will always be fo that the Bell Telephone Company has employed the "Pipe Drain System" as electrolytic protection to their lead-sheath covered ca

The writer has visited several hundred cities, in the last 26 y (1893-1919) and has never failed to observe this condition.

(Springfield, Ohio, February 11, 1914, Report)

Notwithstanding these facts, Mr. H. S. Warren, electrical en eer, American Telephone and Telegraph Company, and Mr. E True, of the Central Union Telephone Company, in their joint re with the National Bureau of Standards on Springfield, Ohio, d February 11, 1914, recommend that "**No metallic connections betw the water or gas pipes and the railway return circuit should permitted.**"

The chief purpose of this is to dissuade other owners of sub face metallic structures, in Springfield, Ohio, from interfering their own proposed "Pipe Drainage System."

See page 7, paragraph 5, of the Springfield, Ohio, report, da February 11, 1914, for verification.

(St. Louis, Missouri, May, 1914, Report)

In May, 1914, Mr. Howard S. Warren and Elam Miller, bot the American Telephone and Telegraph Company, made a joint re

electrolytic conditions with special reference to the "Insulated
turn Feeder System" in the Mississippi-Ann Substation District
the United Railways Company, St. Louis, Mo. They did not even
ention the "Pipe Drainage System," yet the Southwestern Tele-
one and Telegraph Company uses the Pipe Drainage System
rough the entire city of St. Louis, Mo., for electrolytic protective
rposes.

COMMENTS ON WISCONSIN RAILROAD COMMISSION REPORT

Dated June 13, 1918

(Printed by E. E. Brownell, March 1, 1919)

In this printed report, on page 44, will be noted a statement of
dwin S. Mack, attorney for the Wisconsin Telephone Company of
ilwaukee, Wis., in which Mr. Mack says: "that he has no evidence
offer," "that every utility in Milwaukee bears a close relationship,
ne to the other," and a lot of other irrelevant statements.

The Wisconsin Telephone Company, with the consent and ap-
roval of The Milwaukee Electric Railway and Light Company, as
ell as the predecessors of The Milwaukee Electric Railway and
ight Company, have maintained an independent Pipe Drainage Sys-
m of their own for the last 19 years, to the personal knowledge of
e writer, and from all apparent indications since the beginning of
lectric street railway traction in Milwaukee, Wis., or April 4, 1890.

This state of affairs has wrought immeasurable electrolytic de-
truction to gas and water pipe lines intersecting the various lines of
ad-sheath covered cables of the Wisconsin Telephone Company.
et for all these years the Wisconsin Telephone Company, as one of
he principal parties, has permitted this damage and destruction to
ontinue from bad to worse.

The moment any apparent change is suggested that might place
heir lead-sheath covered cables in electrolytic jeopardy, be it ever
o slight, one would imagine from their protestations, that their whole
roperty rights were about to be abrogated and confiscated and their
elephone system rendered inoperative.

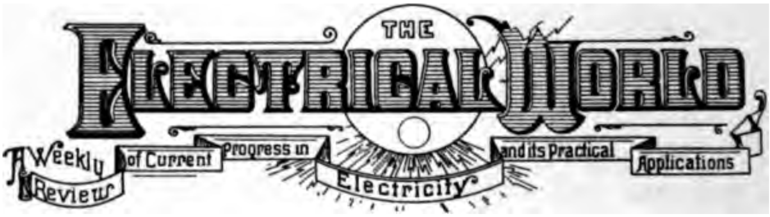
The policy of the American Telephone and Telegraph Company,
s well as its subsidiary Bell Telephone Companies, from the early
ays to the present date, has been merciless toward the public and its
ompetitors, contemptible in its dealings and without due respect
nd regard to anybody or anything but itself.

Today, this company is the greatest public service octopus upon the American continent, but still seeking favors from the public in increased rates.

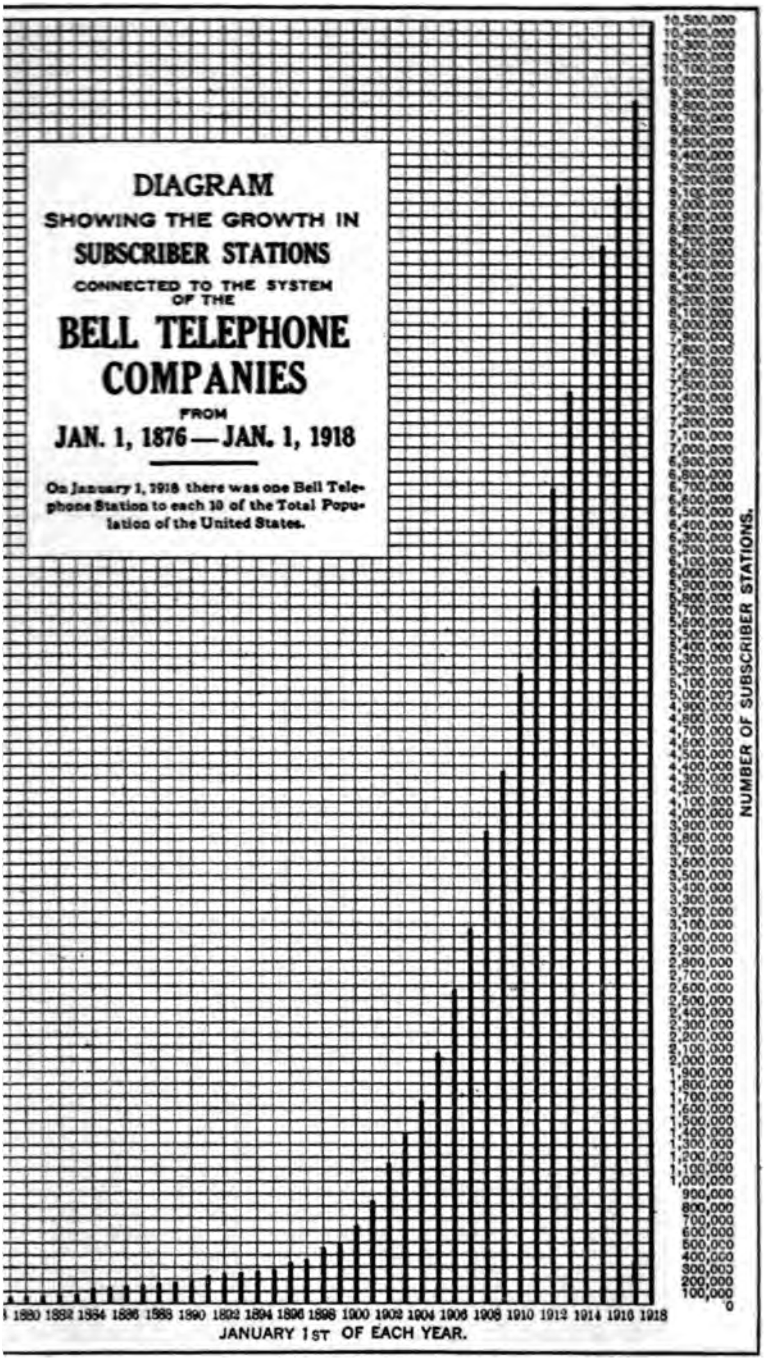
Even the most learned financial (disinterested) men in the country have never been able to solve the connection between the American Telephone and Telegraph Company and the Western Electric Company.

ELECTROLYSIS OF UNDERGROUND TELEPHONE CABLES IN MILWAUKEE

(The Electrical World, May 25, 1895, Page 617)


The
Electrical World
A Weekly Review of Current Progress in Electricity and its Practical Applications

"Electrical Engineering" for May reprints a recent paper by Mr. Dexter giving a sketch of the conditions found in the subways of the Wisconsin Telephone Company a year ago, and the measures taken to alter these conditions in order to prevent damage to the lead cables through electrolysis; a complete map of the system was made showing the voltage between the cables and the earth in each manhole; the results of a number of these measurements are given; in one case a current of 27 amperes at five volts was found flowing from the water main to the cable; out of 144 manholes the cables in 35 were positive to the earth while in the majority they were negative with a maximum of six volts, in which the current flowed from the earth to the cables; at these points there is nothing to fear but at the points where the current was leaving the cable to the earth it was destroying the covering. The cables were cleaned and covered as much as possible with asphalt paint and number 0 copper wires were run from a number of manholes connecting the cables with the negative busbar at the railway powerhouse; this changed the readings from a positive to a negative value; this system of wires carries a current of 210 amperes back to the station; in all of the manholes the cables are at present negative with regard to the earth and there is now no point in the system where the current leaves the cables except by the copper conductors; no destroying effect is therefore taking place.



DIAGRAM

SHOWING THE GROWTH IN

SUBSCRIBER STATIONS

CONNECTED TO THE SYSTEM OF THE

BELL TELEPHONE COMPANIES

FROM

JAN. 1, 1876—JAN. 1, 1918

On January 1, 1918 there was one Bell Telephone Station to each 10 of the Total Population of the United States.

STATEMENT

WISCONSIN TELEPHONE COMPANY

INCOME ACCOUNT....YEARS ENDING DECEMBER 31.

Year of	No. of Stations Connected	Gross Revenue	Gross Expenses	Net Earnings	Rate Percent.	Dividends Paid	Undivided Profits
1891	6,280	....	....	....	......	....	....
1909	77,470	$2,678,442	$2,104,113	$ 574,329	6%	$540,129	$ 34,200
1910	87,110	2,981,194	2,286,034	695,160	7½%	675,900	19,260
1911	99,786	3,241,583	2,506,156	735,427	8%	720,960	14,467
1912	115,592	3,600,076	2,865,461	734,615	8%	720,960	13,655
1913	126,340	3,946,637	3,026,146	920,491	8%	720,960	199,531
1914	137,903	4,324,182	3,313,649	1,010,533	8%	720,960	289,573
1915	144,851	4,548,645	3,411,289	1,137,356	8%	720,960	416,396
1916	156,978	4,938,375	3,624,413	1,313,962	8%	720,720	573,242
1917	*	6,095,413	4,053,127	1,043,286	8%	800,000	242,286
1918	*	5,336,581	4,277,235	1,059,346	8%	880,000	176,662

GENERAL BALANCE SHEET, DECEMBER 31, 1918.

(Filed with the Interstate Commerce Commission)

ASSETS:		LIABILITIES	
Property Account	$19,488,425	Capital Stock	$11,000,000
Bonds and Stocks Owned	139,545	Premium on Capital Stock	33
Other Investments	3,026	Funded Debt	63,500
Materials and Supplies	497,465	Loans and Notes Payable	28,000
Cash on Hand	236,435	Current Liabilities	491,218
Bills and Notes Receivable	14	Taxes Accrued	413,960
Current Accounts	451,957	*Deferred Credit Items	6,736,353
Deferred Debit Items	173,299	Profit and Loss	2,182,102
		Other Long Term Debt	75,000
TOTAL	$20,990,166	TOTAL	$20,990,166

NOTE: For some unexplainable reason, the Wisconsin Telephone Company pays the enormous sum of 4½% of its Gross Receipts to the American Telephone and Telegraph Company. This is in addition to the 8% dividends and large undivided profits. (Yet they asked for increased rates, notwithstanding. E. E. B., September 1, 1919.)

PART XIV

COMMENTS OF E. E. BROWNELL

On Testimony of G. W. Van Derzee, Assistant to Vice-President, The Milwaukee Electric Railway and Light Company, Before the Railroad Commission of Wisconsin, Held in Milwaukee, Wis.

(June 13, 1918)

Accompanying this report is a 48-page printed report, printed by the writer from a rough typewritten copy, of the proceedings of the Railroad Commission of Wisconsin, held in the office of Mr. Clifton Williams, City Attorney, Milwaukee, Wis., on June 13, 1918.

This session was called by Commissioner Allen, at the request of The Milwaukee Electric Railway and Light Company, for the purpose of having investigated the adequacy of provision and preventing interference with service furnished by other public utilities using subsurface metallic structures, and the provisions of Section 1797m-102o.

The writer herewith states the following criticisms upon the testimony of G. W. Van Derzee, given June 13, 1918:

1. Mr. Van Derzee first admits that he is the "Commercial Engineer and Engineer of Electrical Machinery" for The Milwaukee Electric Railway and Light Company and has been for the past five years. That he is also a graduate engineer.

2. Mr. Van Derzee further admits on page 8 of the printed report, that his knowledge upon the subject of Electrolysis has been gained by the reading of books and technical literature. His testimony clearly proves that his statement is correct, for his testimony is that of a theorist painting a word picture of Electrolysis. His evidence lacks practicability and shows he has no intimate personal knowledge of the subject matter. This every engineer should have before he should be permitted to qualify as an electrical expert in any line.

3. On page 14 of the report Mr. Van Derzee further admits that electrolytic action at the calked pipe joints, of a distributing system,

is only hearsay with him, and that he never saw much manifestations of electrolytic corrosion.

4. On page 15 of the report, Mr. Van Derzee still further admits and states, that the Pipe Drainage System can cause the water in the service pipes to become hot by reason of the electrical current flow passing over the service pipes. The writer earnestly wonders if the college where Mr. Van Derzee graduated from taught the use of the B. T. U. application. It seems not by such evidence.

5. The writer has carried over 1,500 amperes of direct current over a section of 6-inch c. i. water main, for days at a time, without heating the running water in it to an appreciable extent. The copper equivalent of the 6-inch c. i. water main was about 220,000 c. m., and which would have, in copper, a maximum electrical carrying capacity of about 300 amperes, yet the writer carried more than five times this amount of current.

6. In the City of Pittsburgh, Penna., the writer has carried over 6,500 amperes of return, direct, current of electricity on a 42-inch water main without any rise in temperature of the pipe or the water. The water running about 100 feet per minute of lineal distance. As Mr. Van Derzee is a college graduate, he might easily have calculated the amount, in amperes, that would be necessary to raise the temperature of the water one (1) degree Fahrenheit in a 6-inch c. i. water main with the water moving 100 feet (lineal) per minute. It would indeed be amusing to see the answer, in amperes, that he would get—judging from his testimony.

7. Also on page 15 of the report, Mr. Van Derzee thinks that the electrical current flow over a gas main in the ground can cause ignition of the gas, and a resultant gas explosion. It would be the most interesting information to know of such strange phenomena from a scientific standpoint.

8. It is indeed very queer that Mr. G. W. Van Derzee should have been selected by The Milwaukee Electric Railway and Light Company to give expert electrical testimony before the Railroad Commission of Wisconsin, when they had in their employ a Cornell University graduate of September 1897-June 1901, and who received the degree of "A.B." from such an excellent institution.

9. How frightfully ridiculous Mr. Van Derzee's evidence becomes on the use of the Pipe Drainage System, as stated throughout his testimony, when all one has to consider is the indisputable fact,

that the Pipe Drainage System, in principle, has been in use (by The Milwaukee Electric Railway and Light Company's own solicitation) since in the Summer of 1893. From 1893 to 1896 under the Milwaukee Street Railway Company's instructions. (See re-printed report of O. M. Rau, Electrical Engineer, Milwaukee Street Railway Company, of 1893, in this report.)

10. On page 18 of the report, Mr. Van Derzee states that in 1893 the Pipe Drainage System was not the prime means of electrolytic mitigation. This does not harmonize with the written report of O. M. Rau of 1893.

11. All that a practical electrical engineer has to do, is to read the evidence of Mr. Van Derzee to prove his inability to properly handle this subject. The relationship between Mr. Van Derzee and the skilled practical electrical engineer (he need not be necessarily a college graduate, such as Thomas A. Edison was not) is the same as between a carpenter and a practical surgeon. Both in the latter case can amputate limbs, but how?

12. The worst part of the whole testimony of Mr. G. W. Van Derzee is that it tends to seriously mislead the Railroad Commission of Wisconsin, as to what is really the correct condition and the proper solution of the electrolysis problem. Possibly, it might have been done for this sole purpose of deception, as to the facts and figures. Attorneys have much to learn in electrical engineering before properly versed.

13. On page 32 of the report, Mr. J. D. Shaw states the electric street railway started in 1891. It was in April, 1890. He also does not know the date of the organization of his own company. It was in January, 1896. Notice how radically wrong Mr. Van Derzee's statements on page 32 differ with Mr. O. M. Rau's written report of 1893. It would be well for Mr. Van Derzee to read pages 544 and 545 of the "Street Railway Review" of December, 1893, that he may know more what he is talking about.

14. On pages 32, 33 and 34 of the report, Mr. James D. Shaw states that The Milwaukee Electric Railway and Light Company, from 1912 to 1913, spent the sum of $114,143.48 for copper cables used in the construction of the "Insulated Rail Return System" of electrolytic mitigation. The writer believes this statement to be grossly erroneous, as no characterized differentiation is given between copper cables used as "Rail Returns" and wires of the "Insulated Rail Return" systems. The whole testimony of Mr. Van Derzee, or any part of it, would not stand close scrutiny by a skilled electrical engineer.

15. In this session of June 13, 1918, not an engineer appeared in behalf of the City of Milwaukee, Wis., to rebut any of the theoretical statements of Mr. Van Derzee, so that the whole affair was a one-sided one, which could not help but leave Commissioner Allen to draw false and seriously misleading conclusions.

16. How any public utility commission could possibly draw an intelligent and equitable conception of electrolytic conditions and the proper form of electrolytic mitigation, in the City of Milwaukee, from the testimony of Messrs. Shaw, Van Derzee, Mack, Simpson and Arthur Jeremiah Sweet, is beyond the constructive faculty of the writer.

17. There will never be a satisfactory solution of the electrolysis problem, in the City of Milwaukee, until there is a better organization perfected which has more practical talent upon this subject.

18. Furthermore, no public service commission can pass properly and equitably upon this important subject without the technical assistance of an engineer thoroughly familiar with all of the phases of this subject matter. Such a commission is liable to do an irreparable injustice to the pipe owners and operators, through misleading statements on the part of selfish electric street railway companies.

19. The Beloit, Wis., electrolytic mitigation plan is one excellent example of where the Railroad Commission of Wisconsin was woefully and unknowingly ill-advised to the detriment of all parties concerned in the City of Beloit, Wisconsin. What assurance has the City of Milwaukee that a similar mistake will not be made in Milwaukee with continuing serious injury to the Milwaukee Water Works system?

20. It is very self-evident, throughout all of the years from 1893 to 1919, inclusive, that the use of the Pipe Drainage System in the City of Milwaukee, as installed by the various electric street railway companies upon their own volition and knowledge, has been miserably applied. Mr. G. W. Van Derzee evidently has not been well informed of electrolytic conditions prior to 1917.

21. The inter-connecting of water pipes and rails throughout the City of Milwaukee, from 1893 to some later date, by means of over 50 odd copper attachments, irrespective of the electrical polarity between the rails and the water pipes, has been one very serious electrolytic menace to the Milwaukee Water Works System. This bit of information, officially recorded, may be a bit enlightening to Mr. Van Derzee. The writer found indisputable evidence of these many connections in his survey of August, 1900.

PART XV

AN ACT CREATING THE NATIONAL BUREAU OF STANDARDS

Chapter H—The Bureau of Standards

(1908 United States Statutes from West Publishing Company)

§ 921. **Bureau Established**—The Office of Standard Weights and Measures shall hereafter be known as the National Bureau of Standards. (March 3, 1901, c. 872, § 1, 31 Stat. 1449.)

§ 922. **Functions of Bureau**—The functions of the bureau shall consist in the custody of the standards; the comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the government; the construction, when necessary, of standards, their multiples and subdivisions; the testing and calibration of standard measuring apparatus; the solution of problems which arise in connection with standards; the determination of physical constants and the properties of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere. (March 3, 1901, c. 872, § 2, 31 Stat. 1449.)

§ 923. **Same; for Whom Exercised**—The bureau shall exercise its functions for the government of the United States; for any state or municipal government within the United States; or for any scientific society, educational institution, firm, corporation, or individual within the United States engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments. All requests for the services of the bureau shall be made in accordance with the rules and regulations herein established. (March 3, 1901, c. 872, § 3, 31 Stat. 1449.)

§ 924. **Testing Materials for District of Columbia**—Hereafter materials for fireproof buildings, other structural materials, and all materials, other than materials for paving and for fuel, purchased for and to be used by the government of the District of Columbia, when necessary in the judgment of the commissioners to be tested, shall be tested by the Bureau of Standards under the same conditions as similar testing is required to be done for the United States Government. (March 4, 1913, c. 150, 37 Stat. 945.)

§ 925. **Officers and Employes**—The officers and employees of the bureau shall consist of a director, at an annual salary of five thousand dollars; one physicist, at an annual salary of three thousand five hundred dollars; one chemist, at an annual salary of three thousand five hundred dollars; two assistant physicists or chemists, each at an annual salary of two thousand two hundred dollars; one laboratory assistant, at an annual salary of one thousand four hundred dollars; one laboratory assistant, at an annual salary of one thousand two hundred dollars; one secretary, at an annual salary of two thousand dollars; one clerk, at an annual salary of one thousand two hundred dollars; one messenger, at an annual salary of seven hundred and twenty dollars; one engineer, at an annual salary of one thousand five hundred dollars; one mechanician, at an annual salary of one thousand four hundred dollars; one watchman, at an annual salary of seven hundred and twenty dollars, and one laborer, at an annual salary of six hundred dollars. (March 3, 1901, c. 872, § 4, 31 Stat. 1449.)

Current appropriation for Bureau (Director, $6,000), see Act March 3, 1917, c. 163, § 1, 39 Stat. 1114.

§ 926. **Director; Powers and Duties; Report**—The director shall be appointed by the President, by and with the advice and consent of the Senate. He shall have the general supervision of bureau, its equipment, and the exercise of its functions. He shall make an annual report to the Secretary of the Treasury, including an abstract of the work done during the year and a financial statement. He may issue, when necessary, bulletins for public distribution, containing such information as may be of value to the public or facilitate the bureau in the exercise of its functions. (March 3, 1901, c. 872, § 5, 31 Stat. 1449.)

§ 927. **Appointment of Officers and Employes**—The officers and employees provided for by this Act, except the director, shall be appointed by the Secretary of the Treasury, at such time as their respective services may become necessary. (March 3, 1901, c. 872, § 6, 31 Stat. 1450.)

§ 927a. **Apprentices; Promotion**—Apprentices in the Bureau of Standards may be promoted after satisfactory apprenticeship with the approval of the Civil Service Commission, to positions corresponding to the journeyman grades for which their duties logically prepare them, without regard to apportionment; Provided, that they thus acquire no rights to transfer to other lines of work. (July 16, 1914, c. 141, § 1, 38 Stat. 502.)

§ 928. **Absence of Director**—Hereafter in the case of the absence of the Director of the Bureau of Standards the Secretary of Commerce and Labor may designate some officer of said bureau to perform the duties of the director during his absence. (March 4, 1911, c. 237, § 1, 36 Stat. 1231.)

§ 929. **Fees**—For all comparisons, calibrations, tests, or investigations, except those performed for the government of the United States or state governments within the United States, a reasonable fee shall be charged, according to a schedule submitted by the director and approved by the Secretary of the Treasury. (March 3, 1901, c. 872, § 8, 31 Stat. 1450.)

§ 930. **Regulations**—The Secretary of the Treasury shall, from time to time, make regulations regarding the payment of fees, the limits of tolerance to be attained in standards submitted for verification, the sealing of standards, the disbursement and receipt of moneys, and such other matters as he may deem necessary for carrying this Act into effect. (March 3, 1901, c. 872, § 9, 31 Stat. 1450.)

§ 931. **Visiting Committee**—There shall be a visiting committee of five members to be appointed by the Secretary of the Treasury, to consist of men prominent in the various interests involved, and not in the employ of the government. This committee shall visit the bureau at least once a year, and report to the Secretary of the Treasury upon the efficiency of its scientific work and the condition of its equipment. The members of this committee shall serve without compensation, but shall be paid the actual expenses incurred in attending its meetings. The period of service of the members of the original committee shall be so arranged that one member shall retire each year, and the appointments thereafter to be for a period of five years. Appointments made to fill vacancies occurring other than in the regular manner are to be made for the remainder of the period in which the vacancy exists. (March 3, 1901, c. 872, § 10, 31 Stat. 1450.)

ACTIVITIES OF THE NATIONAL BUREAU OF STANDARDS IN ELECTROLYSIS INVESTIGATIONS AND MITIGATIONS

By E. E. BROWNELL, B. E. E.

The following articles are brief statements of the field activities of the National Bureau of Standards' representatives on electrolytic investigations, surveys and mitigations to September, 1919:

PITTSBURGH, PENNSYLVANIA

In the summer of 1905, the writer conducted a careful electrolytic survey for the City of Pittsburgh, Penna., upon the Pittsburgh Bureau of Water. The cost of this was divided equally between the City of Pittsburgh, Penna., and the Pittsburgh Railways Company.

The writer's printed report, dated September 1, 1905, described the electrolytic conditions found upon the water works distributing system.

Beginning July 21, 1906, and ending January 23, 1908, the writer installed an electrolytic mitigation system upon the distributing system of the Pittsburgh Bureau of Water. The total cost of this was paid by the Pittsburgh Railways Company. The writer's printed report upon this electrolytic mitigation was dated September 14, 1909.

Upon its own volition, so far as the writer has ever been able to learn, the National Bureau of Standards sent representatives to the City of Pittsburgh, Penna., for the purpose of obtaining actual information relating to electrolytic corrosion, or action, around the lead-calked, cast-iron, bell and spigot, water-main joints of the Pittsburgh Bureau of Water.

The Pipe Drainage system, installed by the writer, in the City of Pittsburgh proper, had been in operation since January 23, 1908, or a little over two (2) years before the National Bureau of Standards made its investigation.

The investigation of the National Bureau of Standards, in Pittsburgh, Penna., began on June 24, 1911, and was finished on July 20, 1911, or a total of 26 days.

During these 26 days, fifty-seven (57) lead-calked, cast-iron, bell and spigot, water-main joints were examined, out of a total of about 200,000 lead-calked, cast-iron, water-main joints on the distributing system of the Pittsburgh Bureau of Water.

The Pittsburgh Bureau of Water made all of the requisite street excavations, through costly paving, for the representatives of the National Bureau of Standards. It was understood, quoting by the authority of E. E. Lanpher, Pittsburgh Bureau of Water, that the City of Pittsburgh, Penna., was to be given a report upon the findings of the National Bureau of Standards. After repeated requests, the National Bureau of Standards' representatives left the City of Pittsburgh without any information being given, thus violating the promise they gave. The Pittsburgh Bureau of Water paid practically the entire cost of this investigation, and the Pittsburgh Railways Company nothing.

Two reports upon this primitive electrolytic investigation were made, however, to Mr. F. Uhlenhaut, chief engineer of the Pittsburgh Railways Company, dated August 7, 1911, and January 19, 1912.

It was a physical impossibility for the National Bureau of Standards to have determined electrolytic action at the lead-calked, cast-iron, water-main joints on the Pittsburgh Bureau of Water, under conditions said to have been employed by them.

The National Bureau of Standards not only violated its promise to the City of Pittsburgh, Penna., but gave what evidence they had of joint electrolysis to the Pittsburgh Railways Company, which information cost the Pittsburgh Railways Company nothing.

Thus the National Bureau of Standards left the irresistible impression that they were ashamed to report their findings to the chief interested party—the City of Pittsburgh, Penna. This is a very queer act coming from a department of the United States Government.

ERIE, PENNSYLVANIA

In the spring of 1911, the National Bureau of Standards made an electrolytic survey in the City of Erie, Penna., the Erie Water Works Department participating in the investigation.

See following letter from Mr. George C. Gensheimer, Secretary, Erie Board of Water Commissioners, which is self-explanatory:

UNITED STATES GOVERNMENT EXPERTS WILL TEST WATER PIPES

Erie, Pa.—Experts of the United States Government Bureau of Standards are coming to this city to make tests of the local water mains to determine the extent of the action of electrolysis in the pipes. Burton McCollum of Washington, has arrived in the city to take up this work, and he will soon have a force of men with him. It is expected that the active work will commence about July 1, when a survey of all water pipes will be made. The experts come to Erie at the expense of the government and they will be given all possible assistance by the local Water Board.—Municipal Journal, June 14, 1911.

COMMISSIONERS OF WATER WORKS,

in the City of Erie, 701 French St.

Erie, Penna., May 29, 1919.

H. P. Bohmann, Supt.,
Department of Public Works, Milwaukee, Wisconsin.

Dear Sir: In answer to yours of the 27th inst. in reference to survey made by the National Bureau of Standards on electrolytic investigation in this city, beg to say that in the spring of 1911 a survey was made by the above mentioned Bureau but we have never received a written report of the results.

They had access to all of our previous surveys made by the late A. A. Knudson and others which had been made by N. H. Fenkell, of Detroit, but was then acting as engineer for the Commissioners.

The Commissioners bore a very small portion of the expense of this survey. An arrangement was made whereby we were to furnish laborers necessary for excavating the street, wherever the field men designated. In some instances, we had to repair portions of the streets excavated. However, this was a very small part of the expense. They had one or two men here for perhaps one or two weeks but as stated before, we were never able to get a report, although we had written them frequently and were told that the report had never been published. Now, whether it was subsequently published or not, we do not know, as after a time the matter was dropped.

The traction company have striven to correct the trouble whenever it was brought to their attention and have constantly had their engineer go over their lines. We are not entirely free from it but have less now than we had—say as long as eight or ten years ago. We had charged to the Buffalo and Lake Erie Traction Company, more or less expense for tearing up pavements and repairs which they are declining to pay on the plea that we are not doing anything towards the protection of the water pipes, which pick up the current from their lines. They also complained recently of us when we called their attention to some trouble in the outskirts of the city, that we had laid a large 12-inch feeder a considerable distance but did not notify them of our laying of this line, connecting it up with another 12-inch line several miles from the city, saying that by our laying this 12-inch line and connecting it up with another 12-inch line it changed the whole system of electric current. They also complained that we do not put insulating joints in our pipe as has been done by the Natural Gas Company (how this could be done we are at a loss to know as we do like most other water departments, lead our joints solidly).

If we can be of further service to you we are at your command. We have reports made of surveys in our city by Mr. A. A. Knudson at two different times and while they are old they may be of some advantage to you—and beg to remain,

Yours very truly,

GEORGE C. GENSHEIMER,
Secretary.

ST. LOUIS, MISSOURI

In the summer of 1912, the National Bureau of Standards went St. Louis, Mo., and there conducted experiments relating to the ficacy of the "Insulated Rail Return System," as applied in the lississippi-Ann Substation District of the United Railways Comany.

The report on this work is reprinted in the "Electric Railway ournal," pages 116 to 123 inclusive, dated January 17, 1914.

This is the first case of installing an electrolytic mitigating sysem, by the National Bureau of Standards, by applying their own heoretical knowledge in an actual demonstration by themselves.

In 1912, about ten (10%) per cent of the total electrical energy ised in the propulsion of the cars on the United Railways Company vas delivered from the Mississippi-Ann Substation.

It appears rather strange that the remaining ninety (90%) per ent of St. Louis, Mo., was allowed to go unmitigated, if the Insulated Rail Return System was all that the National Bureau of Standards claimed for it. This electrolytic mitigation system has not been adjusted or had corrections made to it for the last five (5) years, with electrolytic conditions upon the St. Louis Water Works Department system anything but satisfactory to the municipality.

The City of St. Louis, Mo., has no agreement, either directly or indirectly, through the National Bureau of Standards, or directly with the United Railways Company, for the correction of menacing electrolytic conditions in the City of St. Louis, Mo.

The moment the City of St. Louis, Mo., raises the question, the United Railways Company sends for the National Bureau of Standards, which, with the United Railways Company's assistance, endeavors to quiet the serious apprehensions of the City; and that is about as far as they ever get or have gotten after seven (7) years' efforts. This is a most careless and inefficient manner of doing business. The word of the National Bureau of Standards must not be taken as a contract, as it has no legal standing.

On March 18 and 19, 1914, and on April 8 and 9, 1918, the writer made two electrolytic surveys in the Mississippi-Ann Substation District to determine the efficiency of the "Insulated Rail Return System," in protecting the St. Louis Water Works Department distributing system from menacing and serious electrolytic action from the diverted return current of the United Railways Company. See the copies of the two following affidavits covering the same:

AFFIDAVIT

To Edward E. Wall, Water Commissioner,
City of St. Louis, Missouri.

State of Pennsylvania, Philadelphia County, ss.

Before me, a Notary Public in and for the above named State and County, personally appeared Elijah E. Brownell, a practical Consulting Electrical Engineer and Expert, whose place of business is located at 1418 Walnut Street, Philadelphia, Pennsylvania, who being duly sworn deposes and says, that on March 18 and 19, 1914, he personally made an "Electrolytic Survey" in the City of St. Louis, Missouri, with reference to the water pipe lines of the City of St. Louis and the system of United Railways Company, in the Mississippi-Ann Avenues substation district, and obtained results from which he draws the following conclusions:

1. The maximum and minimum differences of electrical pressures, as found, between the tracks and the water pipe lines as shown and as superimposed upon this electrolytic chart, are absolutely true and correct, as recorded.

2. All of the electrical readings were taken duing the hours of light load with no frost in the ground and with the soil ordinarily damp, and the rails throughout in very intimate physical and electrical contact with the earth.

3. The color "Green" denotes the direction of the current flow from rails to water pipes and into the earth. The color "Red" indicates the current flow from the water pipes through the earth to the rails, a more or less menacing and serious electrolytic condition.

4. This electrical condition is the direct antecedent cause which is inevitably developing serious electrolytic corrosion upon the water pipe lines where they are electrically positive to the rails, and the said electrolytic action is governed by the current flow passing from the water pipe lines through the earth to the rails under the various differences of electrical pressures. In other words, the electrolytic condition, as a whole, is unquestionably a serious and menacing one to the water pipes of the City of St. Louis, Mo.

5. The electrolytic mitigating system in vogue at this time when this electrolytic survey was made is known as the "Insulated Rail Return System," and was installed under the direct supervision of representatives of the National Bureau of Standards of Washington, D. C., by E. B. Rosa, Burton McCollum and H. K. Logan, as described in the Electric Railway Journal on January 17, 1914. The cost of the copper cables is said to be worth $25,920.00.

6. Now, therefore, affiant deposes and says, that the "Insulated Rail Return System" as installed in the said district, is both costly and inefficient in operation to the United Railways Company, and the distorted electrical and subsequent electrolytical conditions are a menace to the water pipe lines of the City of St. Louis, Missouri, and in affiant's opinion, the said electrolytic mitigating system is impractical and a failure from both points

of view, and more especially an injustice to the pipe owners and operators to ask them to accept such an electrolytical condition as electrolytic immunity from serious electrolytic action or corrosion.

7. Electrolytic immunity means to keep the water pipe lines electrically negative and remove the current from them without any appreciable injury to them; anything short of this guarantee by the railway company is both unfair and unwarranted, and should be refused as the proper protection by the owners and operators of lead-calked cast-iron piping systems.

ELIJAH E. BROWNELL.

Sworn to and subscribed before me by the said Elijah E. Brownell on this 24th day of July, 1914.

SAMUEL C. MILLWARD,

Notary Public in and for Philadelphia County, Pennsylvania.
My commission expires March 11, 1917.

AFFIDAVIT

To Clifton Williams, City Attorney, Milwaukee, Wisconsin, and Edward E. Wall, Water Commissioner, City of St. Louis, Missouri.

State of Pennsylvania, Philadelphia County, ss.

Before me, a Notary Public in and for the above named State and County, personally appeared E. E. Brownell, a Consulting Electrical Engineer and Expert, whose place of business is located at 1418 Walnut Street, Philadelphia, Pennsylvania, who being duly sworn deposes and says, that on April 8 and 9, 1918, he personally made an "Electrolytic Survey" in the City of St. Louis, Missouri, with reference to the water pipe lines of the City of St. Louis and the system of United Railways Company, in the Mississippi-Ann Avenues substation district, and obtained results from which he draws the following conclusions:

1. The maximum and minimum differences of electrical pressures, as found, between the tracks and the water pipe lines and between the water pipe lines and the surrounding earth, as shown upon the electrolytic charts, are absolutely true and correct as recorded.

2. All of the electrical readings were taken during the hours of average load with no frost in the ground and with the soil ordinarily damp, and the rails throughout in very intimate physical and electrical contact with the earth.

3. The color "Green" denotes the direction of the current flow from rails and the earth to water pipes. The color "Red" indicates the current flow from the water pipes into the earth and to the rails, a menacing and serious electrolytic condition.

4. This electrical condition is the direct antecedent cause which is inevitably developing serious electrolytic corrosion upon the water pipe lines where they are electrically positive to the earth and rails, and the said electrolytic action is governed by the current flow passing from the water pipe lines into the earth and to the rails under the various differences of electrical pressures. In other words, the electrolytic condition, as a whole, is unquestionably a serious and menacing one to the water pipes of the City of St. Louis, Missouri.

5. The electrolytic mitigation system in vogue at this time when this electrolytic survey was made is known as the "Insulated Rail Return System," and was installed about four years ago under the direct supervision of representatives of the National Bureau of Standards of Washington, D. C., by E. B. Rosa, Burton McCollum and H. K. Logan, as described in the Electric Railway Journal on January 17, 1914. The cost of the copper cables was said to be $25,920.00.

6. Now, therefore, affiant deposes and says, that the "Insulated Rail Return System" installed in the said district, is both costly and inefficient in operation to the United Railways Company, and the distorted electrical and subsequent electrolytical conditions are a menace to the water pipe lines of the City of St. Louis, Missouri, and in affiant's opinion, the said electrolytic mitigation system is impractical and a failure from both points of view, and more especially an injustice to pipe owners and operators to ask them to accept such an electrolytical condition as electrolytic immunity from serious electrolytic action or corrosion.

7. Electrolytic immunity means to keep the water pipe lines electrically negative to rail and earth, and remove the current from them without any appreciable injury to them; anything

short of this guarantee by the railway company is both unfair and unwarranted, and should be refused as the proper protection by the owners and operators of lead-calked cast-iron piping systems.

8. Affiant further deposes and says, that there is no written agreement between the City of St. Louis, Missouri, and the United Railways Company for the maintenance and inspection of this electrolytic mitigation system. The City of St. Louis, Missouri, demands nothing specific and the United Railways Company guarantees nothing definite to be accomplished to protect such property from the ravages of electrolytic deterioration—a most careless manner of doing business, at the best, which can never bring about satisfactory results under any form of electrolytic mitigation. The National Bureau of Standards, so far as the City of St. Louis has been informed, has never seen the present electrolytic mitigation since it was installed about four (4) years ago by them. They are theorists and lack practical knowledge. They are not bound by the rules of professional ethics which bind the consulting engineer to his client, neither can they appear in any court of equity as a witness in this important matter.

9. This electrolytic survey was made primarily for obtaining specific data to be used by the City of Milwaukee, Wis., in an injunction suit against The Milwaukee Electric Railway and Light Company by the affiant who is acting for the City of Milwaukee, Wisconsin.

ELIJAH E. BROWNELL.

Sworn to and subscribed before me by the said E. E. Brownell on this 25th day of May, 1918.

WM. FRED DREISBACH,

Notary Public in and for Philadelphia County, Pennsylvania.
My commission expires March 9, 1919.

Commending the above work of the National Bureau of Standards on the installation of the "Insulated Rail Return" in the Mississippi-Ann Substation District of the United Railways Company of St. Louis, Mo., is a printed report, dated May, 1914, by Albert F. Gantz, Professor of Electrical Engineering, Stevens Institute of Technology, Hoboken, New Jersey; Frank N. Waterman, Consulting Engineer, New York City; Samuel S. Wyer, Consulting Engier, Columbus, Ohio; Howard S. Warren and Elam Miller, both the American Telephone and Telegraph Company, New York ty.

(Professor Gantz died a tragic death on July 29, 1917.)

From any engineering angle, good business methods or organiz- ion principles, the work on the electrolytic mitigation in the Miss- sippi-Ann Substation District, as executed by the National Bureau Standards, in the opinion of the writer, is without merit.

The use of pipe drainage was condemned in both of the above eports, directly or by inference.

The United Railways Company and the Union Electric Light nd Power Company, of St. Louis, Mo., and The Milwaukee Elec- ric Railway and Light Company are all controlled by the North merican Company, of 30 Broad Street, New York, N. Y.

SPRINGFIELD, OHIO

In the early part of the year of 1913, the National Bureau of tandards experimented with the installation of the "Insulated Rail eturn System" in the City of Springfield, Ohio, as applying to the peration of The Ohio Electric Railway Company and The Springfield ailway Company. The Ohio Electric Railway Company is an in- erurban electric railway system.

Under date of July 7, 1913, there was issued by the National ureau of Standards a lengthy typewritten report, covering 93 pages, etting forth the "Insulated Rail Return System" merits, as applied within the City of Springfield, Ohio.

On December 26, 1912, the City of Springfield, Ohio, The Ohio lectric Railway Company and E. E. Brownell, of Philadelphia, enna., entered into a valid and binding electrolytic mitigation ontract. Owing to the assertion of The Springfield, Ohio, Gas ompany, that the Insulated Rail Return System was the most fficient form of electrolytic mitigation, the above contract was tem- orarily set aside in order that the National Bureau of Standards night make a comparative test of the efficacy of the "Insulated Rail eturn System," as applied by the National Bureau of Standards.

On February 11, 1914, the National Bureau of Standards, together rith an organized local electrolysis joint utility committee of Spring- eld, Ohio, issued a 35-page printed report covering this work, which is herewith reprinted and made a part of the writer's Milwaukee report.

See page No. 7 of the reprinted National Bureau of Standards report on Springfield, Ohio, dated February 11, 1914, for a concrete example of recommendation on electrolytic mitigation principles, which expressly condemns the use of the Pipe Drainage System, in connection with any part of an electrolytic mitigation system.

AFFIDAVIT

State of Pennsylvania, Philadelphia County, ss.

Before me, a Notary Public in and for the above named State and County, personally appeared Elijah E. Brownell, a practical Consulting Electrical Engineer and Expert, whose place of business is located at 1418 Walnut Street, Philadelphia, Pennsylvania, who being duly sworn deposes and says, that on April 3 and 4, 1914, he personally made an "Electrolytic Survey" in the City of Springfield, Ohio, with special reference to the water pipe lines of the City of Springfield, Ohio, and the system of The Springfield Railway Company and The Ohio Electric Railway Company, and obtained results from which he draws the following conclusions, nothing being done upon The Springfield, Troy and Piqua Railway Company, The Springfield and Washington Railway and The Springfield and Xenia Railway, which are interurban railways with their powerhouses outside the city limits, with very defective rail bonding.

1. The maximum and minimum differences of electrical pressures, as found, between the tracks and the water pipe lines, as shown and as superimposed upon this electrolytic chart, are absolutely true and correct electrical readings, as recorded.

2. All electrical readings were taken during the hours of light load with no frost in the ground, but with the soil considerably damp, and with rarest exceptions, in physical and intimate electrical contact with the rails.

3. The color "Green" denotes the direction of the current flow from the rails into the earth and to the water pipe lines. The color "Red" indicates the return current flow from the water pipe lines through the earth to the rails, a more or less menacing and serious electrolytic condition of the water pipe lines.

4. This electrical condition is the direct antecedent cause that is inevitably developing serious electrolytic corrosion upon the water pipe lines where they are electrically positive to the rails, and the said electrolytic action is governed by the current flow passing from the water pipe lines through the earth to the rails under the various differences of electrical pressures. In other words, the electrolytic condition, as a whole, is unquestionably a serious and menacing one to the water pipe lines of the City of Springfield, Ohio.

5. The electrolytic mitigating system in vogue, at the time that this electrolytic survey was made, is known as the "Insulated Rail Return System," and was installed under the supervision of representatives of the National Bureau of Standards of Washington, D. C., by Dr. S. W. Stratton, Burton McCollum, G. H. Ahlborn and H. K. Logan, assisted by Professor Albert F. Gantz, and others too numerous to mention, as per reports dated July 7, 1913, and February 11, 1914.

6. Now, therefore, affiant deposes and says that the Insulated Rail Return System, as installed in the City of Springfield, Ohio, is both costly and inefficient in operation to The Springfield Railway Company and The Ohio Electric Railway Company, and the extremely distorted electrical and subsequent electrolytical condition is a menace to the water pipe lines of the City of Springfield, Ohio, and in affiant's opinion, the said electrolytic mitigating system is impractical and a failure from both points of view, and especially an injustice to the pipe owners to ask of them to accept such menacing electrolytical conditions as electrolytic immunity. It holds out false hopes to both sides of this issue.

7. Electrolytic immunity means to keep the water pipe lines electrically negative and remove the current from them without any appreciable injury to them; anything short of this guarantee by the railway companies is both unfair and unwarranted, and should be refused by the pipe owners and operators as not the proper electrolytic immunity upon lead-calked cast-iron water piping system, or any other piping system not having insulated pipe joints.

8. Under the terms of a contract dated December 26, 1912, between the City of Springfield, Ohio, and The Ohio Electric Railway Company the affiant is the Intermediary Consulting

Electrical Engineer until his appointment has been revocated by both parties.

ELIJAH E. BROWNELL.

Sworn to and subscribed before me by the Elijah E. Brownell on this 24th day of July, 1914.

SAMUEL C. MILLWARD,

Notary Public in and for Philadelphia County, Pennsylvania.
My commission expires March 11, 1917.

The electrolytic conditions, in the City of Springfield, Ohio, on November 5, 1918, were found to be as menacing, by the writer, as those electrolytic conditions prior to the installation of the "Insulated Rail Return System" by the National Bureau of Standards in 1913-1914. There is no appreciable improvement.

For five (5) years the electrolytic mitigation, as installed by the National Bureau of Standards, in the City of Springfield, Ohio, has been going from bad to worse. All of this destruction is taking place under the control of the local electrolysis board, guided and approved by the National Bureau of Standards, who have done nothing with the electrolytic mitigation in Springfield, Ohio, since 1914. It is grossly neglected and was most inefficiently operating on November 5, 1918.

The City of Springfield, Ohio, has no contract, except the one with The Ohio Electric Railway Company, for they seem indifferent to a subject which brought all the alleged technical talent in the country to Springfield, Ohio, in 1913-1914. Now no one cares.

The writer is still awaiting the final approval of this work in the City of Springfield, Ohio, by the National Bureau of Standards, before continuing his unfinished electrolytic mitigation by the Pipe Drainage System on The Ohio Electric Railway Company, which was mutually stopped in December, 1912, six and one-half (6½) years ago, to accommodate dissenting parties.

CHICAGO, ILLINOIS

Under date of December 21, 1912, Prof. Dugald C. Jackson, of Madison (University), Wisconsin, with Dr. E. B. Rosa of the National Bureau of Standards, and H. S. Warren of the American Telephone and Telegraph Company, made a very exhaustive (theoretical) report to Mr. E. G. Cowdery, Vice-President, Peoples Gas Light and Coke Company, of Chicago, Illinois. It is said that this report cost the Peoples Gas Light and Coke Company a fabulous sum.

In this report (see pages 21 to 27, inclusive) the Pipe Drainage System is also condemned, as a practical method of electrolytic mitigation, directly or indirectly.

This is the first known example of a representative of the National Bureau of Standards being employed by a privately owned public service corporation on matters pertaining to electrolytic conditions.

This report is in opposition to the question raised by the electric street railway companies of the City of Chicago, Illinois, as to why the Pipe Drainage System should not be applied to the subsurface metallic structures for electrolytic mitigative purposes.

In the summer of 1913, it is said that Mr. Burton McCollum, Associate Physicist of the National Bureau of Standards, was employed directly by the Chicago Railways Company, in an attempt to give technical weight against the City of Chicago, Illinois, who had on July 15, 1912, passed a very rigid "Electrolysis Ordinance" under direction of Ray Palmer, City Electrician, Department of Electricity, City of Chicago, Illinois. The electric street railways companies claimed that it would require $22,000,000.00 to comply with this ordinance, and even then the Pipe Drainage System would have to be used conjunctively with the ordinance requirements.

Thus we find Dr. Rosa and Mr. McCollum, if all reports be true, selling their positions and theoretical knowledge to whomsoever is willing to pay the price for data and information bought and paid for by the taxpayers of the United States. They appear to be acting as United States Government experts by day and as consulting electrical engineers by night. All in a single day they seem to enjoy both privileges to the personal benefit of the representatives of the National Bureau of Standards.

Another serious objection to representatives of the National Bureau of Standards accepting compensation from privately owned, public service corporations in matters opposing the wishes of the municipalities, is that a city is nothing more than an arm of the state and the state of the United States Government, so that they (representatives of the National Bureau of Standards) are advising against themselves, as a department of the United States Government, through the State and the municipality.

This peculiar buying and selling of information, which is sai to be practiced extensively by representatives of the National Burea of Standards may, possibly, be legal, but nevertheless it is unethica unwarranted and in bad form. It lessens the dignity of both the go ernmental and professional vocations. To either be one or the othe is the American way.

The writer has the direct word of a prominent corporation atto ney of Chicago, Ills., as to the above statement relating to the e ployment of Mr. Burton McCollum in 1913, by the Chicago Railw Companies.

ALTOONA, PENNSYLVANIA

In the fall of 1914, certain selfish and unscrupulous city official of the City of Altoona, Penna., solicited the aid of Congressman W W. Bailey to bring the National Bureau of Standards to Altoona, Penna., for personal and political purposes. Thus the representatives of the National Bureau of Standards became the apparently willing tools of these unprincipled persons.

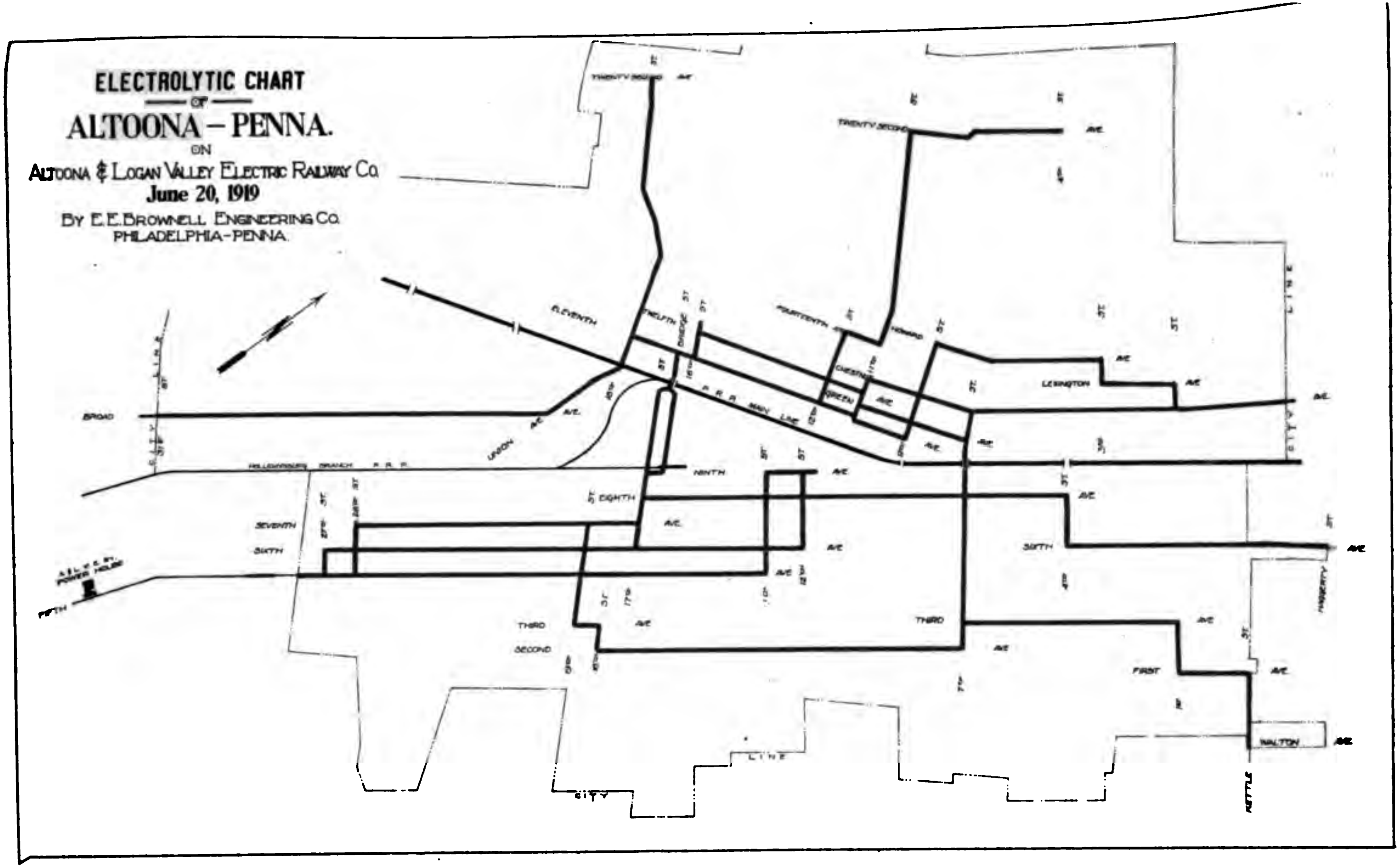
The writer had, in active and efficient service, an electrolytic mitigating system in the City of Altoona, Penna., as applied to the water distributing system of the Altoona Water Works Department. This electrolytic mitigation was covered by a legal, bona-fide contract made by and between the City of Altoona, Penna., the Altoona and Logan Valley Electric Railway Company and E. E. Brownell, of Philadelphia, Penna., all provisions of which were being complied with and the electrolytic mitigation system in splendid working order.

Notwithstanding the legal, ethical and moral rights of the writer, the National Bureau of Standards, with the consent of the City of Altoona, Penna., began to tear out the writer's electrolytic mitigation system, and to install the "Insulated Rail Return System," thus defying all legal and ethical rights of all other parties concerned.

A restraining order issued by Thos. J. Baldridge, Judge of Court of Common Pleas, Blair County, Pennsylvania, granted on October 21, 1914, stopped further depredations on the part of the National Bureau of Standards and their unscrupulous political friends.

The conduct of the representatives of the National Bureau of Standards, in this instance, convinced the writer that these men were devoid of all professional ethics, and not entitled to the confidence, respect and dignity which should go to the members of a branch of the United States Government.

ELECTROLYTIC CHART
OF
ALTOONA – PENNA.
ON
ALTOONA & LOGAN VALLEY ELECTRIC RAILWAY CO.
June 20, 1919
BY E. E. BROWNELL ENGINEERING CO.
PHILADELPHIA-PENNA.



ATIONS

The writer finally gave his consent to test out the plan of "In- lated Rail Return System" in the City of Altoona, Penna., provided, owever, that complete restoration of the existing electrolytic miti- ation system be made promptly upon completion of their system.

In a few weeks' trial the "Insulated Rail Return System," as in- alled temporarily by the National Bureau of Standards in the City Altoona, Penna., was tested out and a 178-page typewritten re- ort made by the National Bureau of Standards upon the efficacy of eir "Insulated Rail Return System" with comments upon the effi- ency of the Pipe Drainage System, installed by the writer and in cellent working order.

This 178-page typewritten report of the National Bureau of tandards, upon Altoona, Penna., electrolysis conditions, as stated ove, was not dated. This does not seem to be a very good ractice in issuing reports from a United States Government Depart- ent—the National Bureau of Standards.

Pipe Drainage was also condemned, directly and by inference, in is report, issued sometime (undated) during the last months of 14 or the first months of 1915.

On June 19, 20 and 21, 1919, all of the distributing system of e Altoona Water Works Department was tested by the writer, and as found to be electrically negative to the surrounding earth. This nstitutes an absolutely immune electrolytic condition of the water orks system.

The City of Altoona, Penna., now has a city-manager form of unicipal government, as well administered as any other city of like ze in the United States, regardless of the form of municipal govern- ent.

AN AFFIDAVIT

Approving the Maintenance and Operation of the Electrolytic Mitigating System in Altoona, Pennsylvania, for the City of Altoona, Pennsylvania, and the Altoona and Logan Valley Electric Railway Company

State of Ohio, Montgomery County, ss.

Before me, a notary public in and for the above named State and County, personally appeared Elijah E. Brownell, a practical Consulting Electrical Engineer and Expert, whose place of business is located at 1418 Walnut Street, Philadelphia, Philadelphia County, Pennsylvania, who being duly sworn deposes and says as follows:

1. That he is the Practical Consulting Electrical Engineer and Expert between the City of Altoona, Pennsylvania, and the Altoona and Logan Valley Electric Railway Company, Altoona, Pennsylvania, under a contract dated April 24th, 1913.

2. Affiant says that he has acted as the Practical Consulting Electrical Engineer and Expert under said contract whereby affiant is empowered under said contract to supervise the initial installation and maintenance of the electrolytic mitigating system with respect to the return current diversion from the Altoona and Logan Valley Electric Railway Company.

3. That the said Altoona and Logan Valley Electric Railway Company has installed and put into operation an efficient electrolytic mitigating system in accordance with the provisions of Article First of said contract of April 24, 1913, as set forth in an affidavit dated December 7, 1913, the maintenance of which is further set forth in an affidavit dated March 27, 1914, to the parties hereto.

4. That affiant again personally made on July 31 and August 1, 1914, an electrolytic survey on the city water system of the City of Altoona, Pennsylvania, and found the electrolytic mitigating system aforesaid to be in the same excellent working order. This survey being the second semi-annual electrolytic survey after the completion of the said electrolytic mitigating system, and it revealed the absence of any appreciable deteriorating electrical currents of electricity of the Altoona and Logan Valley Electric Railway Company affecting the water works distributing system of the City of Altoona, Pa.

5. Furthermore, the water system was found to be entirely electrically negative to the tracks or metallic ground circuits of the Altoona and Logan Valley Electric Railway Company, as well as electrically negative to the surrounding earth at all points along the Altoona and Logan Valley Electric Railway Company's tracks, and that all the provisions and conditions of the said contract dated April 24, 1913, have been most fully complied with by the Altoona and Logan Valley Electric Railway Company, under the direct supervision of the affiant, as shown by this survey, with accompanying electrolytic chart, dated July 31, and August 1,

1914, which shows the immune electrolytic conditions in graphic form.

6. Electrolytic immunity means to keep the water pipe lines electrically negative and remove the current from them without any appreciable injury to them.

7. That this affidavit is made to set forth the opinion of the affiant as the Practical Consulting Electrical Engineer and Expert under said contract of April 24, 1913.

ELIJAH E. BROWNELL.

Sworn to and subscribed before me by the said Elijah E. Brownell on this 17th day of August, 1914.

PHILO G. BURNHAM,

Notary Public in and for Montgomery County, Ohio.
My commission expires January 4, 1917.

ELYRIA, OHIO

(From Municipal Journal, September 16, 1915, Page 440)

ELECTROLYSIS MITIGATION IN ELYRIA

Elyria, Ohio.—Changes in the feeding distances of the powerhouse are recommended in the preliminary report on electrolysis mitigation made by Burton McCollum and K. H. Logan, in the form of a paper which has been issued by the Bureau of Standards, Department of Commerce. From data furnished by the city and the Cleveland, Southwestern and Columbus Railway Company, the feeding distances of the Elyria powerhouse are found to be too long and the potential gradients too high. It is recommended that the gradients be reduced to 0.3 volt per 1,000 feet average for 24 hours by the addition of a substation, the interconnection of the tracks of the two electric railways, and the installation of an insulated return-feeder system. The saving in power due to the reduced feeding distance is shown to be more than sufficient to pay the annual charges on the additional investment of $34,373. The plan provides for 800 kilowatts additional substation capacity, improved operating conditions, and substantial elimination of electrolysis.

OMAHA, NEBRASKA

In the latter part of the year 1916, the National Bureau of Standards conducted an electrolytic survey in the City of Omaha, Nebraska, and at the same time attempted to install a three-wire system, having 1,200 volts, direct current, between the trolley sections; also reversed polarity of substation.

The City of Omaha, Neb., with a member of each of the privately owned, public service utility companies or corporations, constituted a local electrolysis committee. Judging only from reports emanating from Omaha, Neb., results have been far from satisfactory.

The recommendations made by the National Bureau of Standards, in the Omaha, Neb., electrolytic survey, are the first instance where representatives of the National Bureau of Standards have recommended the use of the Pipe Drainage System, or any other system of electrolytic mitigation other than the "Insulated Rail Return System." These recommendations of the Pipe Drainage System, however, provide for its use in conjunction with the "Insulated Rail Return System."

The writer expects to make a thorough test and electrolytic survey in the City of Omaha, Neb., some time during the month of October, 1919, on behalf of the City of Milwaukee, Wisconsin.

SPRINGFIELD, MASSACHUSETTS

In the latter part of the year of 1914, the National Bureau of Standards' representatives made considerable efforts to successfully install the "Three-Wire System" in the City of Springfield, Mass.

These experiments were carried on by the National Bureau of Standards for many months, and then finally abandoned in the early part of 1917 before any disinterested engineer could test out the efficiency of this new plan of electrolytic mitigation. The "Insulated Rail Return System" was set aside, with the idea that the "Three-Wire System" would be a much more effective means for combating electrolytic deterioration.

The subject was again revived in Springfield, Mass., in the early part of the year of 1919, and the "Three-Wire System" is now in course of construction.

The letter reproduced hereafter explains the present condition of the "Three-Wire System" in the City of Springfield, Mass.

The new form of electrolytic mitigation will be tested out very thoroughly, by the writer, provided, however, that the National

Bureau of Standards will finally say, for once, that they have finished it, as they have never finished any particular piece of electrolytic mitigation work known, in the United States and placed their final approval on it. It is always finished, except—this or that. Years have come and years have gone, and yet we fail to find one (1) completed and well conducted form of electrolytic mitigation in any city of the United States, that the National Bureau of Standards has successfully adjusted. It is always a case of migrating to new fields of interest by the National Bureau of Standards and leaving the old ones forgotten and neglected.

VARIOUS QUOTATIONS AND LETTERS

SPRINGFIELD, MASSACHUSETTS

(From Municipal Journal, September 10, 1914, Page 357-8)

REPORT ON ELECTROLYTIC ACTION

Springfield, Mass.—The movement to stay the decay in the city's system of water pipes as well as in the underground conveyors of every other public service corporation is now well started. The government engineers who surveyed the city carefully last month report that, while the situation here is not acute, yet underground structures, including the biggest water mains in the central part of the city, are suffering, and are already badly pitted. The damage already done is caused by uncontrolled currents of electricity flowing away from the tracks of the street railway company, running along any pipes of metal they have encountered and corroding the metal wherever they were deflected. The method of furnishing the power to the system and of handling the return flow must be changed, principally by the installation of several substations distributed around the city instead of the one main plant, according to the opinion of Dr. E. B. Rosa, acting director, and Burton McCollum, assistant physicist for the United States Bureau of Standards. They are the men who directed the survey, which required the services of several men during most of July. The survey was made at the request of the public service associates of the city, most of whom felt they were suffering from the electrolytic action of the street railway company's current.

J. Torr Harmer, president of the company, said the recommendations of the engineers if carried out would mean a large initial expenditure by the company in the building of the subpower stations and the other reorganization of the system. The question of who should bear this expense is now being debated, though it is understood that in the beginning it was agreed that if all the other corporations paid for the survey the railway company would ask for no help in putting the recommendations into effect, so far as its system was concerned. The report states that the company stands to win in the long run by a considerable saving in operating expense. E. E. Lochridge, chief engineer of the water department, said that he did not consider the condition of the water mains to be serious at present. None of them will have to be replaced at once, even though some are pitted deeply. By the measurements of potential differences between street railway returns and fire hydrants, the investigators found "some rather bad conditions" to exist in Indian Orchard and Chicopee, and especially in Chicopee Falls. Judging from the situation as they found it, the engineers concluded there must be some metallic connection between underground pipes and the railway negative return, but the engineers of none of the corporations knew of any. The government men finally unearthed an uncharted connection under a house near the railway power plant, where two copper wires were found to be taking from 100 to 250 amperes from a water pipe.

The fact that the experts found electrolysis to be going on steadily in various parts of the city, and that they recommend remedial measures at the earliest practicable date has stimulated the corporations to swift action. What they hope will happen is that the Board of Trade or some other central organization will take the matter up in an attempt to bring the railway company and the other utilities together, so that something may be done to stop the ravages of electrolysis, and that the work may be accomplished on a basis satisfactory to everybody concerned. The vital interest which the city has in the matter through the damage to the water system, may prompt the city government to act.

WEST SPRINGFIELD

Country Is Watching Experiment on West Side—Springfield Street Railway Pioneer in Trying to Save Current Lost by Electrolysis.

(From the Springfield, Mass., Daily Republican,
Wednesday, Dec. 6, 1916)

Electrical America is watching the first extensive and energetic attempt to eliminate or reduce the destructive forces of electrolysis, which is in process of experiment on the lines of the Springfield Street Railway Company west of the Connecticut River. Since Sunday the company has been testing out a new sectional three-wire system. The experiment is being watched with great interest by electrical and street railway officials and experts throughout the country.

Burton McCollum, electrical engineer of the Bureau of Standards of the Department of Commerce, has been here since Sunday with other experts to make a close examination of the local company's tests, which will continue for two weeks. Mr. McCollum declares that no hurried conclusions concerning the success or failure of the new system are yet possible or advisable.

No method has been devised in this country that has proved positive protection for underground metal carriers against damage by leakage of electrical currents into the earth. The experts who are following closely the development of the new scheme are watching not only for a decrease in the forces of electrolysis, but also for what is almost as important, a possible increase in the cost of operation. Some power may be lost by this new three-wire system.

C. V. Wood, president of the Springfield Street Railway Company, has received already many enquiries as to the outcome of the experiment from other railways in the country. If the method is successful in diminishing the damaging effects of electrolysis the company will extend the sectional wire system to its other lines. It will also be undoubtedly adopted by other trolley companies. This experiment was considered two years ago, but owing to an unfortunate delay in the manufacture and shipment of equipment it was not undertaken at that time.

The trolley company has been co-operating with the bureau of standards in this matter. There are two three-wire systems that have been compiled by this bureau, the sectionalized and the so-called parallel arrangements. The three-wire system chosen for trial here has two important technical advantages and also is said to have certain economic desirabilities. The bureau has explained the three-wire system as a plan by which the feeding district is divided into sections and alternate sections are supplied by feeders running directly from the positive buss, while the other sections are supplied by feeders from the negative buss, the difference of potential between the two busses being avoided. The tracks serve as the neutral agent and convey the current from the cars in one section to those in the adjoining section and return the unbalanced power to the powerhouse.

THE CITY OF SPRINGFIELD, MASSACHUSETTS

Municipal Water Works

June 18, 1919.

Mr. E. E. Brownell,
No. 1418 Walnut St., Philadelphia, Penna.

Dear Mr. Brownell: Sometime ago the three-wire system was installed in West Springfield and tests made. It was found, however, that there had been some wrong placing of wires so this district was not again tested or put fully into operation. Since that time the whole power situation for the Springfield Street Railway has changed and power from outside sources has been brought in and other stations have been established, and my understanding is that the three-wire system is being applied in such a manner that in the new power-feed the entire city would be on the three-wire system.

About two weeks ago representatives of the Bureau of Standards were here and tests were started on all portions of Springfield and West Springfield, and I believe also some of the other cities and towns in the district. Before the tests were completed I believe that the Street Railway found it necessary to shift back to the old feeding system temporarily, and I have not received any information as to the outcome of the whole proposition. One of the men from this office was on the work and he stated that there had been a wonderful improvement in the conditions at certain points where he had been on the work previously. As I stated, however, I believe the three-wire system is not at present in operation, but is to be within a short period.

Very truly yours,

ELBERT E. LOCHRIDGE,
Chief Engineer.

NEW ORLEANS, LOUISIANA

In the latter part of the year of 1917, the National Bureau of Standards made an electrolytic survey of the City of New Orleans, La., at the initial request of the New Orleans Sewerage and Water Board.

This report is in line with many others made by the National Bureau of Standards on electrolytic conditions and mitigations.

Nothing has been done in the City of New Orleans, La., to com-y with any part of the recommendations of the National Bureau of andards up to June, 1919.

SEWERAGE AND WATER BOARD OF NEW ORLEANS

Room 502 City Hall Annex

New Orleans, La., June 11, 1919.

r. E. E. Brownell,
City of Milwaukee, Milwaukee, Wis.

Dear Sir: Replying to yours of the 6th inst., would say that e National Bureau survey in New Orleans was made in the latter rt of 1917. Little of anything has been done looking to the im- ovement of electrolysis conditions so far as I know.

The Railway and Light Company has been in a great deal of iancial trouble, and I do not think they have given serious con- ieration to the electrolysis problem. The Bureau of Standards me to New Orleans to make its survey at the joint request of the ailway Company, the Sewerage and Water Board and the Tele- ione Company, all of whom co-operated and paid part of the small st of the survey. The Sewerage and Water Board were the chief overs, however, in getting the National Bureau to do this work.

Yours very truly,

GEORGE G. EARL,
General Superintendent.

MONTGOMERY, ALABAMA

During the year of 1917, the National Bureau of Standards made n electrolytic survey in the City of Montgomery, Alabama, but noth- ng was ever done to correct menacing electrolytic conditions there, s stated by Mr. W. T. Perry, Superintendent, Montgomery Water Works Department.

ST. PAUL, MINNESOTA

In the Summer of 1917, the National Bureau of Standards made n electrolytic survey in the City of St. Paul, Minnesota.

This report contains 82 typewritten pages with 16 accompany- ng cuts, and is dated Washington, D. C., October 1, 1917, and signed y S. W. Stratton, Director.

The National Bureau of Standards was requested to come to St. Paul, Minn., and make an electrolytic survey by consent of the following public utility companies, and the St. Paul Water Works Department.

1. Twin City Rapid Transit Co.
2. Northern States Power Co.
3. St. Paul Gas Light Co.
4. Northwestern Telephone Co.
5. Tri-State Telephone Co.
6. Western American Telegraph Co.
7. North American Telegraph Co., and
8. Water Works Department, City of St. Paul.

The following three concrete recommendations were made in this report, namely:

1. That the Pipe Drainage System be installed upon all of the six (6) lead-sheath covered, underground, cable systems. They deemed it the best form of electrolytic mitigation. (See page 24 of their typewritten report.)

2. That a restricted Pipe Drainage System be applied to the water piping system of the City of St. Paul Water Works Department, with as limited number of connections as possible.

3. That a local Electrolysis Committee be formed between the above named companies and City of St. Paul, Minn.

In the St. Paul typewritten report (1917) there are 14 tables of electrical readings, covering a total of 49 pages of typewritten matter.

It seems almost incredible that a United States Government Bureau should send out from Washington representatives to compile such electrical information and not even state the month, day, hour or minute that many of these readings were taken, or the conditions under which they were made.

It would appear from the report that the electrolytic survey was made from June 26 to July 6, 1917. No time is mentioned in the report, as to whether the time was before or after meridian.

The records bear the earmarks of an amateur engineer, for many of the 16 plates of maps, charts, etc., have no dates but 1917.

The St. Paul Water Works paid 20% of the total cost of this kind of an electrolytic survey.

Up to June 1, 1919, no electrolytic mitigating system had yet en started in the City of St. Paul, Minn., to follow out the recom-ndations of 1917, or two years ago.

A striking feature in the St. Paul, Minn., report (1917) is that r. E. R. Shepherd was paid a salary of $510.00 for services rendered. is places Mr. Shepherd in the position of accepting money for ser-es rendered the seven (7) public utility companies and the City of . Paul, Minn., while in the employ of the United States Govern-ent. Therefore Mr. Shepherd seemingly assumes the position of ing a consulting engineer, in business for himself, but financially cked by the United States Government through liberal appropria-ons from Congress.

Mr. Shepherd could hardly have selected a better financial sup-orter than "Uncle Sam."

How about the young professional engineer, whether or not he college bred? What financial backer has he? None. How can he expected to compete (professionally) with engineers financed, pro-ected and sponsored by the United States Government? What chance as he to rise professionally if the principles (or lack of principles) ollowed by the National Bureau of Standards should be applied to ther branches of public service utilities and industrial vocations?

Again—he has none.

There can be no question but that representatives of the National ureau of Standards have taken an unethical advantage of other pro-ssional engineers.

If our engineering standard is to be maintained at its present igh level as an intellectual vocation it will be necessary to hold out least some inducement to the young men who are taking up vari-s professional engineering branches. The present conditions only rve to stifle that legitimate competition which is so necessary if the ponents of any profession are to be kept up to the standard of aximum efficiency.

The electrolysis work which the National Bureau of Standards s been conducting during past years is wrong in principle, false to gineering standards of the profession, and untrue to the purpose r which this department of the United States Government was eated.

It was never intended that representatives of the National Bureau of Standards should prostitute the prestige afforded them by their position, by engaging in professional competition.

The whole situation is unfair and un-American.

It does not give the poor but capable young man an equal chance in the engineering line he is best qualified to pursue.

The writer can not believe that our American Government ever intended to foster such an attitude on the part of one of its departments.

Had this man Shepherd possessed any knowledge of the fundamental principles of professional ethics, he could not have been guilty of the unethical and ungentlemanly conduct displayed in the City of Waterloo, Iowa.

Those readers who are interested will find food for thought by looking up the Dr. Weston-National Bureau of Standards controversy of some years ago.

The chief objections that the writer has to the representatives of the National Bureau of Standards, are that they are unethical, often ungentlemanly, and always impractical. They are trouble-makers, either knowingly or through ignorance, and have been instrumental in causing unnecessary disagreements between the clients of the writer.

The near future will show their intent in so doing.

So long as the writer possesses the power to do so, he will protect his clients against invasion of their rights by the representatives of the National Bureau of Standards. For these rights and privileges are sacred to the writer.

There has been nothing fair or equitable in the treatment accorded the City of Milwaukee, Wis., by the representatives of the National Bureau of Standards.

If the National Bureau of Standards is to be continually extending the scope of its activities in matters of operation, permitting the prestige given it as a part of the United States Government to be exploited to the personal profit of its representatives, and invading e rights and territories of engineers all over this country, what is become of individual initiative and genius? It is these qualities at made our American soldier, sailor and marine the greatest fight-s of the day—it is these qualities, encouraged by a democracy, that ve made our country without an equal in the world; shall they be othered instead of being encouraged?

In the opinion of the writer, the engineering principles of the ational Bureau of Standards have already brought costly and un-cessary waste of time, money and effort. The Springfield, Ohio, ectrolysis situation is a very good example of this extravagance.

In conclusion, the writer hopes for the day to come when it may better understood as to why the National Bureau of Standards s taken such a deep interest in the matter of Electrolysis in the City Milwaukee; this, when the City Council, by a vote of 28 to 6, re-sed to request them to come to the City of Milwaukee.

The City Council is the legislative body that represents the will the citizens of the City of Milwaukee. Why then, when this au-oritative body voted not to have the National Bureau of Standards me to Milwaukee, did it insist upon coming, notwithstanding? here must be a good reason.

ANNUAL APPROPRIATION

Made By The United States Government for National Bureau of Standards at Washington, D. C.

(Pages 131 to 140)

Bureau of Standards: Director, $6,000; physicists—chief $4.800, nd one $4,000, one qualified in optics, $3,600; three at $3,600 each, wo at $3,300 each, four at $3,000 each; assistant to the director, 3,600; associate physicists—five at $2,700 each, five at $2,500 each, ur at $2,200 each, seven at $2,000 each; assistant physicists—twelve $1,800 each, fourteen at $1,600 each, eighteen at $1,400 each; chem-ts—chief $4,800, two at $3,500 each, one at $3,300, one $3,000; asso-ate chemists—three at $2,700 each, three at $2,500 each, one $2,200, ur at $2,000 each; assistant chemists—four at $1,800 each, four at ,600 each, six at $1,400 each; physical chemist, $1,800; laboratory sistants—twenty-three at $1,200 each, eighteen at $1,000 each; lab-atory helpers—two at $840 each, four at $720 each, four at $600 each; aids—fourteen at $900 each, sixteen at $720 each; twenty laboratory apprentices, at $540 each; editor, $2,500; secretary, $2,200; property clerk, $1,800; storekeeper, $1,000; librarian, $1,600; chief clerk, $2,200; clerks—one of class four, three of class three, three of class two, eight of class one. seven at $1,000 each, seven at $900 each, two at $720 each, two telephone operators at $720 each; office apprentices—four at $540 each, two at $480 each, two at $420 each; six elevator boys at $480 each; mechanicians—chief and foreman of instrument shops $2,400, one $1,800, one $1,600, one $1,500, two at $1,400 each, five at $1,200 each, six at $1,000 each, one $900; machinist, $1,200; shop apprentices—two at $720 each, two at $600 each, three at $540 each, three at $480 each; lieutenant of watch, $900; twelve watchmen; skilled woodworkers—foreman of woodworking shops $1,500, one $1,200, two at $1,000 each; skilled laborers—three at $840 each, six at $720 each; draftsman, $1,200; photographers—one $1,400, one $1,200; packer, $840; two messengers; assistant messenger; superintendent of mechanical plant, $2,500; assistant engineers—one $1,600, two at $1,400 each, three at $1,200 each, one $1,000, one $900; two pipe fitters at $1,000 each; ten firemen; glass blowers—one $1,600, one $1,200; glassworker, $1,600, expert optician, $2,000; electricians—one $1,400, one $1.200, one $900, one helper $900; foreman of janitors and laborers, $900; fourteen laborers; janitors—five at $720 each, three at $660 each, one $600; two female laborers, at $360 each; in all, $486,760.00.

For apparatus, machinery, tools, and appliances used in connection with buildings or work of the bureau, laboratory supplies used in the construction of apparatus, machinery, or other appliances, including their exchange; piping, wiring, and construction incident to the installation of apparatus, machinery, or appliances; furniture for laboratories and offices, cases for apparatus, $100,000.00.

For repairs and necessary alterations to buildings, $8,000.00.

For fuel for heat, light, and power; office expenses, stationery, books and periodicals; traveling expenses (including expenses of attendents upon meetings of technical and professional societies when required in connection with standardization, testing, or other official work of the bureau); street car fares not exceeding $100; expenses of the visiting committee; expenses of attendants of American member at the meeting of the International Committee of Weights and Measures; supplies for operation, maintenance, and repair of a passenger automobile and motor trucks for official use, including their exchange; and contingencies of all kinds, $60,000.00.

For grading, construction of roads and walks, piping grounds for water supply, lamps, wiring for lighting purposes, and other expenses incident to the improvement and care of grounds, $7,500.00.

For continuation of the investigation of structural materials, such as stone, clays, cement, and so forth, including personal services in the District of Columbia and in the field, $125,000.00.

For maintenance and operation of testing machines, including personal services in connection therewith in the District of Columbia and in the field, for the determination by the Bureau of Standards of the physical constants and the properties of materials as authorized by law, $30,000.00.

For investigation of fire-resisting properties of building materials and conditions under which they may be most efficiently used, and for the standardization of types of appliances for fire prevention, including personal services in the District of Columbia and in the field, $25,000.00.

For investigation of the standards of practice and methods of measurements of public utilities, such as gas, electric light, electric power, water, telephone, central station heating, and electric railway service, and the solution of the problems, which arise in connection with standards in such service, including personal services in the District of Columbia and in the field, $85,00.00.

For investigation of materials used in the construction of rails, wheels, axles, and other railway equipment, all the cause of their failure, including personal services in the District of Columbia and in the field, $15,000.00.

For testing miscellaneous materials, such as varnish materials, soap materials, inks, and chemicals, including supplies for the Government Departments and independent establishments (69), for the issuance of certificates describing the quality of sample goods submitted for test to the bureau, including personal services in the District of Columbia and in the field, as authorized by law, $30,000.00.

For investigation and standardization of methods and instruments employed in radio communication, including personal services in the District of Columbia and in the field, $30,000.00.

To develop color standards and methods of manufacture and of color measurement, with special reference to their industrial use in standardization and specification of colorants such as dyestuffs, inks, and pigments, and other products, paint, paper, and textiles, in which color is a pertinent property, including personal services in the District of Columbia and in the field, $10,000.00.

To study methods of measurement and technical processes used in the manufacture of pottery, brick, tile,. terra cotta, and other clay products, and in the study of the properties of the materials used in that industry, including personal services in the District of Columbia and in the field, $20,000.00.

To determine experimentally important physical constants of materials essential to the industries or in laboratory investigations, as authorized by law, such as the determination of the value of gravity, thermal conductivities of materials, mechanical equivalent of heat, metallurgical constants such as specific and latent heats of metals and alloys, the electrochemical equivalent of metals, the velocity of light; including data important in the efficient planning of industrial processes, and in the effective utilization of the properties of materials, including personal services in the District of Columbia and in the field, $5,000.00.

To develop methods of testing and standardizing machines, motors, tools, measuring instruments, and other apparatus and devices used in mechanical, hydraulic, and aeronautic engineering; for the comparative of types of apparatus and methods of operation, and for the establishment of standards of performance; for the accurate determination of fundamental physical constants involved in the proper execution of this work; and for the scientific experiments and investigations needed in solving the problems which may arise in connection therewith, especially in response to the requirements of aeronautics and aviation for information of a purely scientific nature, including personal services in the District of Columbia and in the field, $15,000.00.

For the investigation of the problems involved in the production of optical glass, including personal services in the District of Columbia and in the field, $20,000.00.

For purchase, preparation, analysis, and distribution of standard materials to be used in checking chemical analyses and in the testing of physical measuring apparatus, including personal services in the District of Columbia and in the field, $5,000.00.

To investigate textiles, paper, leather, and rubber in order to develop standards of quality and methods of measurement, including

ersonal services in the District of Columbia and in the field,
15,000.00.

For the standardization and design of sugar-testing apparatus;
he development of technical specifications for the various grades of
ugars with particular reference to urgent problems made pressing
y war conditions, especially involving the standardization and manu-
acture of sugars; for the study of the technical problems incidental
o the collection of the revenue on sugar and to determine the funda-
ental scientific constants of sugars and other substances, includ-
g personal services in the District of Columbia and in the field,
20,000.00.

To provide by co-operation of the Bureau of Standards, the War
epartment, the Navy Department, and the Council of National De-
ense, for the standardization and testing of the standard gauges,
rew threads, and standards required in manufacturing throughout
e United States, and to calibrate and test such standard gauges,
rew threads, and standards, including necessary equipment, and
ersonal services in the District of Columbia and in the field,
0,000.00.

For investigating the conditions and methods of use of scales
d mine cars used for weighing and measuring coal dug by miners,
r the purpose of determining wages due, and of conditions affect-
g the accuracy of the weighing or measuring of coal at the mines,
cluding personal services in the District of Columbia, and in the
eld, $15,000.00.

For metallurgical research, including alloy steels, foundry prac-
ce, and standards for metals and sands; castings, rolling, forging,
d the properties of aluminum alloys, prevention of corrosion of
etals and alloys; development of metal substitutes, as for platinum;
ehavior of bearing metals; preparation of metal specifications; in-
estigation of new metallurgical processes and study of methods of
onservation in metallurgical manufacture and products, $25,000.00.

For laboratory and field investigations of suitable methods of
igh temperature measurements and control in various industrial
rocesses and to assist in making available directly to the industries
he results of the Bureau's investigations in this field, including per-
onal services in the District of Columbia and in the field, $10,000.00.

For the moving and installation of present equipment, and the
urchase of new equipment, including personal services in the District
f Columbia and in the field, $100,000.00, to be immediately available.

For the investigation of the principles of sound and their application to military and industrial purposes, including personal services in the District of Columbia and in the field, $5,000.00.

For technical investigations in co-operation with the industries upon fundamental problems involved in industrial development following the war, with a view to assisting in the permanent establishment of the new American industries developed during the war, including personal services in the District of Columbia and elsewhere, $50,000.00, to be available immediately.

BUREAU OF STANDARDS
(SUNDRY CIVIL)

Testing of large scales: for investigation and testing of railroad track scales, elevator scales, and other scales used in weighing commodities for interstate shipments and to secure equipment and assistance for testing the scales used by the Government in its transactions with the public, such as post-office, navy-yard, and customhouse scales, and for the purpose of co-operating with the States in securing uniformity in the weights and measures laws and in the methods of inspection, including personal services in the District of Columbia and in the field, $40,000.00.

PART XVI

RESOLUTION

AUTHORIZING LITIGATION

Proceedings of the Common Council

(Pages 856-857—Oct. 24, 1910)

Ald. Koch—From the Committee on Railroads, presented a report in favor of adopting the following resolution, viz.:

Whereas, The Milwaukee Electric Railway and Light Company s the successor and assignee of the Milwaukee City Railway Company, the West Side Railroad Company, the Cream City Railroad Company, and is operating other lines by virtue of franchises granted directly to it; and

Whereas, On October 14th, 1889, permission was given The Milwaukee City Railroad Company by an ordinance duly passed to change its motive power from horse power to electricity "by means of power produced by electricity conducted upon wires suspended over and above the tracks"; and

Whereas, The West Side Railroad Company was on October 14th, 1899, authorized by an ordinance duly passed to change its motive power from horse power to electricity and "to operate its street railway cars by means of power produced by electricity conducted upon wires suspended over and above its tracks"; and

Whereas, The Cream City Railroad Company was authorized by an ordinance duly passed October 14th, 1889, to change its motive power from horse power to electricity and to operate "its street railway cars by means of power produced by electricity conducted upon wires suspended over and above its tracks"; and

Whereas, By an ordinance passed January 2nd, 1900, The Milwaukee Electric Railway and Light Company was granted a certain franchise and certain grants extending the life of the franchises which had been granted to its predecessors, which said franchise granted to the said company the right to "operate their street railway cars and carriages by means of power produced by electricity conducted upon wires suspended over and above its tracks"; and

Whereas, The Milwaukee Electric Railway and Light Company is not operating its street railway cars by electricity conducted over and above its track, but is in fact operating its cars under its franchises and as assignee of the franchises mentioned above by means of electricity conducted upon a wire suspended over and above its tracks and by means of electricity conducted through its tracks; and

Whereas, The electricity conducted through the tracks of the said The Milwaukee Electric Railway and Light Company is permitted to escape and does escape into the street and there does damage to the water pipes and other underground workings which belong to the city, through the process of electrolysis; therefore

Be It Resolved, By the Common Council of the City of Milwaukee, that the City Attorney be and he is hereby directed to start such proceedings as shall in his opinion be proper to compel The Milwaukee Electric Railway and Light Company to comply with the provisions of its franchises and the franchises of which it is the assignee, in order to stop the process of electrolysis that is now destroying city property, by installing another wire with a double trolley system above and over its tracks for the return current, as was contemplated in the franchises granted to it and in the franchises under which it operates as assignee; and

Be It Further Resolved, That the city attorney be and he is hereby authorized and directed to start such legal proceedings as shall in his opinion be proper and necessary to collect from The Milwaukee Electric Railway and Light Company damages that may have been done by it through the process of electrolysis as mentioned herein to water pipes and other underground workings belonging to the said City of Milwaukee.

Adopted.

FROM THE CITY ATTORNEY AND DEPARTMENT OF PUBLIC WORKS

File Number 12760

Milwaukee, April 16, 1917.

To the Honorable Common Council of the City of Milwaukee.

Gentlemen: The matter of injury to the water pipes of the Milwaukee Water Works done by electrolysis has been heretofore considered by your Honorable Body. On October 24, 1910, page 856, Council Proceedings, 1910-1911, the Council passed a resolution concerning the same, authorizing investigation and litigation. The investigation was made in what is known as the Palmer report and some subsequent investigations were made. This department has been laboring under some difficulty in an attempt to prove what damage has been done within the six year statute of limitations. It seems now imperative to take a different attitude towards the matter because of the apparent impossibility of proving how much of the damage has been done within the statute of limitations excepting in those few cases where the injured pipes have been laid within the last six years.

I now propose to your Honorable Body that we take the matter up purely from a curative point of view and use a part of the appropriation in the present budget for this purpose. This will necessitate an up-to-date survey of the electrolysis situation in Milwaukee. A number of city officials have been informally negotiating with some of the leading authorities on electrolysis in this country, and we are morally certain that there is nothing now in the way of proceeding with the matter. The damage that is being done is in many cases apparent to the naked eye. The loss of eight water mains during the last year is so apparently from electrolysis that even the most skeptical can be convinced of this by mere inspection of the remains of the pipes.

We have collected data on this problem from various American institutions, including the Bureau of Standards of the government, and find that in a great many cities of this country the damage is either mitigated or prevented by various means, depending upon the local situation. The cost of the preliminary service, we are assured from several different sources, should not and will not exceed $1,000. On the face of it this seems a very small amount, considering the magnitude of the problem involved and the great amount of damage being done, and considering further that our water main distribution system is valued at five million dollars, independent of the service pipes, which form more than half of the entire value of the water works system.

I am attaching hereto a communication from the Commissioner of Public Works, recommending to your Honorable Body that an expert be employed without the necessity of making specifications and entering into a formal contract to make the preliminary survey, also a resolution to accomplish this purpose, which will require a three-fourths vote of the Council for adoption.

Respectfully submitted,

CLIFTON WILLIAMS,
City Attorney.

Milwaukee, April 16, 1917.

To the Honorable, the Common Council.

Gentlemen: With respect to employing an expert to make an electrolysis survey of the water pipe systems of the City of Milwaukee, I wish to report to your Honorable Body under the provisions of Section 18 of chapter 5 of the charter, that in my opinion the work can be better and more cheaply done without the intervention of a formal contract, for the reason that it is practically impossible to file specifications such as will insure procuring the most expert and most efficient engineer for this work, and it is also true that competition in this field through competitive bidding would not get for the city the high class, expert service demanded under the circumstances. I am desirous of procuring the very best man that can be secured for this work in the United States, and I am practically sure that the same can be accomplished if the formal contract requirement is suspended. For that reason I attach to this communication a resolution providing for the letting of the work without contract, and respectfully recommend the adoption of the resolution.

Very truly yours,

FRED G. SIMMONS,
Commissioner of Public Works.

File Number 12760

Whereas, The City of Milwaukee owns a five million dollar ater distribution system, which according to information conveyed › this Common Council, is being damaged by electrolysis; and

Whereas, The Commissioner of Public Works under the provi- ons of Section 18 of Chapter 5 of the Charter, has recommended ıat an expert be employed to make a preliminary survey, the said nployment to be without the intervention of a formal contract, and ısigned sufficient reasons therefor; and

Whereas, The City Attorney has reported to this Common Coun- l that said preliminary survey is necessary in order to carry out ıch proceedings as may be necessary to protect the city water pipes om electrolysis damages; therefore be it

Resolved, By the Common Council of the City of Milwaukee, ıat said Commissioner of Public Works be, and he is hereby, author- ed and directed to employ an expert for the purpose of making a :eliminary survey of said electrolytic condition, the cost of same ɔt to exceed One Thousand Dollars ($1,000.00), to be taken from ıe funds set up for this purpose in the budget; and be it further

Resolved, That said Commissioner of Public Works is hereby ıthorized to negotiate with said expert upon a plan looking towards ıe mitigation and abolition of the said electrolysis damages, and to :port said plan to this Common Council for confirmation before final loption.

Referred to the Committee on Water Works-Sewerage.

REPORTS OF THE COMMITTEE ON WATER-WORKS-SEWERAGE TO THE COMMON COUNCIL OF THE CITY OF MILWAUKEE, WISCONSIN

(Page 1062)

Regular meeting, Monday, February 11, 1918, 2:30 o'clock, p. m.

Ald. Grede—From the Committee on Water Works-Sewerage, reported upon File No. 13740, communication from Clifton Williams, Esq., City Attorney, relative to electrolysis, by recommending the adoption of the following resolution:

File Number 13740

Resolution directing City Attorney to commence court proceedings to correct electrolysis damage done by T. M. E. R. & L. Co.

Whereas, The City Attorney has now communicated with this Common Council concerning the electrolysis situation in connection with the Milwaukee Water Works, desiring to have this Common Council decide whether said matter should be arbitrated or litigated; and

Whereas, The Water Works Committee has held several committee hearings on the proposition and all parties interested have been given an opportunity to be heard; and

Whereas, The Milwaukee Electric Railway and Light Company did not submit to said committee any proposition of arbitration acceptable to said committee; and

Whereas, The said company refused a proposition made to have the city's expert and the company's expert select a third expert engineer and all three to act as a board of arbitration; therefore be it

Resolved, By this Common Council, that the City Attorney be and he is hereby directed to start, within the next thirty days, such proceedings in court as shall be necessary to bring about the correction of the electrolysis damage now being done by the current of

The Milwaukee Electric Railway and Light Company to the water pipes and other installation of the city.

Ald. Thompson moved that further action on the foregoing matter be deferred until the next regular meeting.

By unanimous consent, the foregoing motion was withdrawn.

Ald. Thompson moved that further action on the foregoing matter be deferred until later in the meeting.

The motion prevailed.

(Page 1092)

Ald. Friedrich in the chair.

A report of the Committee on Water Works-Sewerage recommending the adoption of a resolution relative to File No. 13740, communication from Clifton Williams, Esq., City Attorney, relative to electrolysis, laid over earlier in the meeting, was taken up at this time.

Ald. Thompson moved that further action on the foregoing matter be deferred until the next regular meeting.

The motion prevailed by the following vote: Ayes 29, noes 7.

Ald. Alldridge, Baumann, Coleman, Grede, Mudroch, Strehlow and Urbanek voting no.

Not voting: The President—1.

There being no further business, the Council thereupon adjourned (4:20 p. m.).

P. F. LEUCH,
City Clerk.

(Page 1104, 1105, 1106)

Regular meeting, Monday, February 25, 1918, 2:30 o'clock p. m.

President Corcoran in the chair.

A report of the Committee on Water Works-Sewerage recommending the adoption of a resolution relative to File No. 13740, communication from Clifton Williams, Esq., City Attorney, relative to electrolysis (Resolutions printed in full in the proceedings of February 11, 1918, at page 1062), laid over from the last regular meeting, was taken up.

Ald. Thompson presented the following minority report:

File Number 13470

Milwaukee, Wis., February 11, 1918.

The undersigned, member of the Committee on Water Works and Sewerage, respectfully dissents from the majority report of said committee recommending for adoption a resolution refusing to arbitrate with The Milwaukee Electric Railway and Light Company, the question of mitigation of electrolysis by a submission of the matter to the National Bureau of Standards by said company and the city, with an agreement on the part of the company to install such system or systems as shall by said Bureau of Standards be found necessary, together with a further agreement on the part of said company to so maintain such system or systems as to conform to all requirements of said Bureau respecting such maintenance; and in lieu of such arbitration instructing the City Attorney to commence an action against said company to provide for the mitigation of electrolysis, for the following reasons:

1. Mitigation of electrolysis being a technical engineering question, should be decided by expert engineers experienced in the question of electrolysis.

2. The city is entitled to the maximum protection afforded in the mitigation of electrolysis by the installation of the most scientific and effective system or systems and the most efficient maintenance and operation of such systems when installed.

3. The National Bureau of Standards, by law made the highest authority on standardization in the United States, a non-political board maintained at the expense of the Government as a part of the Department of Commerce for the purpose of securing to the citizens of the United States impartial, reliable, technical, scientific knowledge, is the proper arbiter and the highest authority on electrolysis and the safest means through which the City of Milwaukee can obtain satisfactory mitigation of electrolysis.

4. It is admitted that no court will prescribe the system to be installed and that the only order to be secured through litigation is one requiring the installation of a sufficient system. The best author-

y on what is a sufficient system being the National Bureau of Stand- ds above described, inasmuch as the company now proposes to stall a system to the satisfaction of said Bureau, there is nothing be gained by such litigation.

5. That such litigation will materially delay the satisfactory set- ement of the electrolysis problem and entail expense upon the city ithout accomplishing any good purpose.

6. That after the determination of such litigation, if favorable the city, the respective parties thereto will be in the same position they are now notwithstanding the expense incurred.

I therefore recommend the adoption of the following resolution lieu of that recommended by the majority of the committee, and at the following be substituted therefor:

Resolved, That the City of Milwaukee, through its proper officers, gotiate an agreement with The Milwaukee Electric Railway and ight Company whereby said Company shall agree, at its own ex- nse, to install and efficiently maintain such system or systems for e mitigation of electrolysis, due to the operation of the street rail- ay of said company in the City of Milwaukee, Wisconsin, as shall ovide practical electrolytic immunity of the Water System of the id city in accordance with the best American practice in single trol- y operation, the installation of such system and the manner of main- ining the same, to be subject to the supervision and approval of e National Bureau of Standards and in accordance with the direc- ons of said Bureau, its officers or representatives; the decision of id Bureau to be final and conclusive as to the proper initial instal- tion of said system or systems and the methods of operation and aintenance thereof, with an agreement on the part of the said city at, pending such installation and a reasonable period of operation ereunder, to establish its adequacy, the city will refrain from insti- ting any proceeding against said company for the installation of y different or additional system of electrolysis mitigation, provided at said company shall proceed with due diligence in the installation f said system.

Respectfully submitted,

S. S. THOMPSON.

Ald. Wittig moved that further action on the foregoing majority d minority reports be deferred until the next regular meeting.

Ald. Szczerbinski moved that the Council do now take a recess until 7:30 o'clock p. m. this day.

By unanimous consent the foregoing motion was withdrawn.

Ald. Friedrich moved that the Council do now take a recess until Thursday, February 28, 1918, at 2:30 o'clock p. m.

The motion prevailed.

P. F. LEUCH,
City Clerk.

(Page 1107)

Recessed meeting, Thursday, February 28, 1918, 2:30 o'clock p. m.

File Number 14174

Common Council, Recessed Meeting, Thursday, February 28, 1918, 2:30 o'clock p. m.

President Corcoran in the chair.

Present: Ald. Alldridge, Altpeter, Baumann, Bogk, Bohn, Bulder, Campbell, Coleman, Doerfler, Elsner, Fass, Friedrich, Grass, Grede, Greene, Grogan, Herrmann, Kempf, Kleis, Koerner, Lukaszewicz, McKinley, Meisenheimer, Morgan, Mudroch, Olsen, Radke, Reynolds, Seidel, Strehlow, Szczerbinski, Thompson, Urbanek, Weiss, Wittig and the President—36.

Excused: Ald. O'Connor—1.

Unfinished Business—Continued

Consideration of Majority and Minority Reports of the Committee on Water Works-Sewerage relative to File No. 13740, communication from Clifton Williams, Esq., City Attorney, relative electrolysis, was continued.

Ald. Thompson moved that the Council resolve itself into a committee of the whole for the purpose of hearing various persons relative to the subject matter under consideration.

By unanimous consent the foregoing motion was withdrawn.

Ald. Alldridge moved that further action on the foregoing matters be deferred until later in the meeting.

The motion prevailed.

(Page 1141, 1142)

Majority and minority reports of the Committee on Water orks-Sewerage relative to File No. 13740, communication from lifton Willams, Esq., City Attorney, relative to electrolysis, laid ver earlier in the meeting, was taken up.

Ald. Morgan moved that the Common Council do now resolve self into a committee of the whole for the purpose of hearing vari- us persons relative to the subject matter under consideration.

The motion prevailed.

Ald. Meisenheimer in the chair.

Mr. A. J. Sweet and Mr. W. A. Jackson appeared in behalf of . M. E. R. & L. Co. and City Attorney Clifton Williams appeared behalf of the City of Milwaukee and addressed the committee rela- ve to the subject matter under consideration.

Ald. Koerner moved that the committee of the whole do now se.

The motion prevailed.

President Corcoran in the chair.

Ald. Meisenheimer, from the committee of the whole, announced at the committee had met and heard Messrs. A. J. Sweet and W. A. ckson, of T. M. E. R. & L. Co., and City Attorney Clifton Williams lative to the subject matter under consideration.

The Chair put the question: "Shall the foregoing minority re- ort be substituted for that of the committee?"

The minority report thereupon failed to be substituted for that the committee by the following vote:

Ayes, 6; Noes, 28.

Ald. Bogk, Friedrich, Kleis, McKinley, Thompson and the Presi- ent voting aye.

Not voting: Ald. Bohn.

Ald. Greene offered the following amendment:

Amend the foregoing resolution as printed in the proceedings of ebruary 11, 1918, at page 1062, first column, by adding at the end of said resolution the following: "That the expert witness fees for the preliminary injunction case shall not exceed $1,000.00."

The foregoing amendment was carried by unanimous vote.

Ald. Thompson moved to amend the foregoing resolution as amended by striking out "1,000" and inserting in lieu thereof "500."

The foregoing amendment was lost.

The foregoing resolution as amended was thereupon adopted by the following vote:

Ayes: Ald. Alldridge, Altpeter, Baumann, Bulder, Campbell, Coleman, Doerfler, Elsner, Fass, Friedrich, Grass, Grede, Greene, Grogan, Herrmann, Kempf, Kleis, Koerner, Lukaszewicz, Meisenheimer, Morgan, Mudroch, Olsen, Reynolds, Seidel, Strehlow, Szczerbinski, Urbanek, Weiss and Wittig—30.

Noes: Ald. Bogk, McKinley, Thompson and the President—4.

Not voting: Ald. Bohn—1.

CERTIFIED COPY OF RESOLUTION

File Number 13740

RESOLUTION

irecting City Attorney to Commence Court Proceedings to Correct Electrolysis Damage Done by T. M. E. R. & L. Co.

Whereas, The City Attorney has now communicated with this ommon Council concerning the electrolysis situation in connection ith the Milwaukee Water Works, desiring to have this Common ouncil decide whether said matter should be arbitrated or litigated; nd

Whereas, The Water Works Committee has held several comittee hearings on the proposition and all parties interested have been iven an opportunity to be heard; and

Whereas, The Milwaukee Electric Railway and Light Company id not submit to said committee any proposition of arbitration aceptable to said committee; and

Whereas, The said company refused a proposition made to have e city's expert and the company's expert select a third expert enineer and all three to act as a board of arbitration; therefore be it

Resolved, By this Common Council that the City Attorney be nd he is hereby directed to start, within the next thirty days, such roceedings in court as shall be necessary to bring about the correcon of the electrolysis damage now being done by the current of he Milwaukee Electric Railway and Light Company to the water ipes and other installation of the city. "That the expert witness es for the preliminary injunction case shall not exceed $1,000.00."

OFFICE OF THE CITY CLERK

Milwaukee, March 25, 1918.

I hereby certify that the foregoing is a copy of a resolution dopted by the Common Council of the City of Milwaukee, on Febary 28, 1918.

P. F. LEUCH, City Clerk.

STATE OF WISCONSIN
CIRCUIT COURT—MILWAUKEE COUNTY

CITY OF MILWAUKEE, Plaintiff.

vs.

THE MILWAUKEE ELECTRIC RAILWAY
AND LIGHT COMPANY, Defendant.

COMPLAINT

The City of Milwaukee, plaintiff, for a cause of action against the defendant alleges as follows:

1. That the City of Milwaukee is a municipal corporation organized and existing under and by virtue of the laws of the State of Wisconsin.

2. That the defendant, The Milwaukee Electric Railway and Light Company, is a corporation organized and existing under and by virtue of the laws of the State of Wisconsin, and is a "person engaged in the transmission of electrical energy" within the provisions of the latter part of section 1780b of the Wisconsin Statutes.

3. That the City of Milwaukee, plaintiff, owns some six-inch cast iron water pipe located a few feet beneath the surface of the ground in Maple Street near the intersection of Clinton Street in the City of Milwaukee, and that said cast iron water pipes are legally and rightfully located in said street as a part of a water works system owned by the plaintiff and are property of the City of Milwaukee within the provisions of the latter part of section 1780b of the Wisconsin Statutes.

4. That the said defendant is engaged in the transmission of electrical energy along said Clinton Street where the same intersects said Maple Street in the City of Milwaukee by transmitting the same and returning it to its power station through the street car rails laid in the said street, and upon information and belief the plaintiff alleges that the electrical energy of the defendant escaped and escapes from the said rails laid in the said street and gets upon and did get upon

the water pipes of the plaintiff laid in said Maple Street and crossing at right angles beneath the tracks of the said defendant in said Clinton Street, and that in leaving the said pipe of the said plaintiff in said Maple Street the said current has done great damage to and is doing great damage to said pipes through a process known as electrolysis, and has so greatly damaged said pipes near the intersection of said Maple and Clinton Streets that the plaintiff has been compelled to replace sections of the said pipe, and that the portions taken out have been reduced to a soft carbon shell by the action of the current of the defendant, which action is known as electrolysis as above alleged, and which said current escaped by leakage from the tracks of the said Company as above alleged herein.

5. That the damage to said pipes by the said escaping current of the said Company does not interfere with or affect the quality of water served by the City of Milwaukee or transmitted through the said pipes and does not interfere with the service furnished by the City of Milwaukee through said pipes, but the said damage is a great injury to the property to the City of Milwaukee, which said injury is caused by the failure of the said defendant Company to perform its duty as prescribed in the latter part of section 1780b of the Wisconsin Statutes, in that the said Company has failed to provide suitable insulation and suitable return wires, or other means of conveying the current through the said street to prevent the above alleged injury being done to the plaintiff's property,—all in violation of the provisions of the latter part of section 1780b of the Wisconsin Statutes.

Wherefore the plaintiff prays for an injunction as provided for in section 1780b, and for the full extent of the protection guaranteed and provided by said section, and for such other relief as it shall be entitled to in the premises.

CITY OF MILWAUKEE,

By Clifton Williams, City Attorney.

State of Wisconsin, } ss.
Milwaukee County, }

Clifton Williams, being first duly sworn, on oath says that he is an officer of the above named plaintiff, City of Milwaukee, to-wit: its City Attorney; that he makes this verification for and on behalf of said city, being thereunto duly authorized, and that the reason why this verification is not made by said City of Milwaukee is because said city is a municipal corporation; that he has read the foregoing complaint and knows the contents thereof; that the same is true to his own knowledge, except as to the matters therein set forth on information and belief, and that as to those matters he believes it to be true.

CLIFTON WILLIAMS.

Subscribed and sworn to before me this 19th day of April, 1918.

MADGE E. MATHE,

Notary Public, Milwaukee County, Wisconsin.

My commission expires November 21, 1920.

STATE OF WISCONSIN

CIRCUIT COURT—MILWAUKEE COUNTY

CITY OF MILWAUKEE, Plaintiff.

vs.

THE MILWAUKEE ELECTRIC RAILWAY
AND LIGHT COMPANY, Defendant.

The above named defendant, by Van Dyke, Shaw, Muskat & Van Dyke, its attorneys, answers the complaint of the plaintiff herein as follows:

1. It admits that the plaintiff, City of Milwaukee, is and was, at all times mentioned in the complaint, a municipal corporation existing under the laws of the State of Wisconsin.

2. It admits that it is, and was, a corporation organized under the laws of the State of Wisconsin, but it denies that in respect to its street railway activities, or, by reason of its operation of a system of electric street railway it is, or was, a person engaged in the transmission of electrical energy within the meaning of section 1780b of the Wisconsin Statutes.

3. It admits that the City of Milwaukee long prior to the commencement of the above entitled action, caused to be laid a certain iron water pipe beneath the surface of Maple Street, a public highway running east and west in said City, and intersecting at approximately right angles, Clinton Street, another highway in said City, and that said pipe was laid beneath the surface of Maple Street at a point near its intersection with said Clinton Street.

4. It admits that said pipe was, and is, connected so as to constitute a part of the water distribution system of the water utility operated by said City of Milwaukee.

5. It alleges that long prior to the commencement of the above entitled action the defendant, pursuant to due authority, constructed a double track line of electric street railway along and upon Clinton Street and across said Maple Street; that the type of electric street

railway so authorized and constructed was one by which the energy for the operation of cars was supplied from an overhead trolley wire; that when cars were operated upon said line a circuit was completed between such trolley wire and the rails upon which such cars were operated and return wires connected therewith so that the motors of said cars were energized by current drawn from such trolley wire and returning by means of the rails and return wires connected therewith; that such type of construction was, at the time said line was constructed, and still is, a standard and approved type of electric railway. The art of making suitable provision for the return of current used for railway operation and of electrolysis mitigation has greatly advanced during the last decade; that said subject has constituted one of the fields of scientific investigation and research of the Bureau of Standards of the Department of Commerce of the United States Government; that the defendant has spent large sums of money for the purpose of making adequate provision for electrolysis mitigation and has been guided by expert engineering advice in the selection of the means and methods employed by it for such purpose; that the provision made by the defendant for such purpose is, and was, at the time of the commencement of the above entitled action, and prior thereto, in accordance with the most approved engineering practice, and was, and is, supported by the great weight of opinion among engineers expert in the field of electrolysis mitigation.

6. It denies that the pipes described in the complaint are being, or have been during the six years last past, damaged by electric current employed in rendering service upon its said railway.

7. It denies that it has, heretofore, or is now violating the provisions of section 1780b and denies that by reason of any fault or failure upon its part the plaintiff is now sustaining, or has sustained during the six years last past, any damage to said pipes so laid upon said Maple Street.

8. It alleges that the only interest of the plaintiff in said water pipes arises out of the fact that said pipes are used as a part of its water distribution system; that the cost of laying said pipes was assessed to, and paid by abutting property owners; that the title of the City of Milwaukee in and to said pipes is special and is limited to the right of the City to use the same for purposes of its water utility; that unless the electrolysis, of which the plaintiff complains, affects the suitableness of said pipes for such service, or renders the same liable

to fail, when employed for the delivery of such service, the said City of Milwaukee is not damaged thereby.

9. It alleges that the provision of suitable equipment for the return of electric current used in the operation of its said line of railway is peculiarly a service matter; that all matters relating to the street railway service of the defendant are subject to the control and regulation of the Railroad Commission of Wisconsin; that said Commission, long prior to the commencement of the above entitled action, had considered the character of the equipment and the method employed by the defendant for electrolysis mitigation and pronounced the matter of electrolysis mitigation to be a service problem. (See 10 W. R. C. R. 247).

10. It further alleges that various public service corporations maintain sub-surface metallic structures in and under various of the highways in the City of Milwaukee including said Maple Street; that the said City of Milwaukee has proposed the introduction of an alleged system of electrolysis mitigation by which current flowing along the rails of the defendant would be drawn onto the pipes of the distribution system of the plaintiff's water utility thereby greatly increasing the hazard to the sub-surface metallic structures of other utilities and jeopardizing the service furnished thereby; that the defendant agreed to submit the reasonableness of the plaintiff's proposal to the decision of the engineers of the United States Bureau of Standards and to abide by such decision, but the plaintiff rejected such offer; that the defendant thereupon, and prior to the commencement of this action, requested the Railroad Commission of Wisconsin to undertake an investigation of the matter of electrolysis prevention, and to prescribe rules and regulations pursuant to the provisions of section 1797m-1020; that prior to the commencement of this action the said Railroad Commission of Wisconsin duly undertook such investigation and thereafter, and on or about the second day of April, 1918, duly gave notice of such investigation to the various public utilities using sub-surface metallic structures in the City of Milwaukee including the water utility of the plaintiff; that said proceeding is now pending and has not been concluded.

11. It denies any knowledge or information sufficient to form a belief as to each and every allegation of the complaint not hereinbefore specifically admitted, denied or otherwise answered.

Wherefore, defendant prays that the complaint of the plaintiff herein be dismissed and that the defendant recover its costs and disbursements herein.

VAN DYKE, SHAW, MUSKAT & VAN DYKE,
Attorneys for Defendant.

Milwaukee County, }
State of Wisconsin, } ss.

F. J. Boehm being first duly sworn, on oath says that he has read the foregoing answer, knows the contents thereof and believes the same to be true; that this verification is made by affiant for the reason that the defendant is a corporation and he is an officer thereof, to-wit: Assistant Secretary, and is duly authorized to make this verification for and on its behalf; that the knowledge and information which are the grounds of his belief are derived from his personal attention to, and supervision of the matters stated in said answer, and information from reports and statements made to him by subordinate officers and agents of said defendent company in the regular course of their duty.

F. J. BOEHM,

Subscribed and sworn to before me this 30th day of April, 1918.

ALMA EPSTEIN,
Notary Public, Milwaukee County, Wisconsin.

TENTATIVE REPORT MADE BY PUBLIC UTILITY CORPORATIONS OF MILWAUKEE, WISCONSIN, RELATING TO A PROPOSED ORDER FROM THE WISCONSIN RAILROAD COMMISSION

(Held in the Office of the Milwaukee Gas Light Company, 9:00 A. M., March 27, 1919)

BEFORE THE RAILROAD COMMISSION OF WISCONSIN

In the Matter of the Investigation, on Request of T. M. E. R. & L. Co., of the Adequacy of Provision for Preventing Interference with Service Furnished by Other Public Utilities Using Subsurface Metallic Structures and the Prescription of Rules and Regulations Necessary to Carry Out the Provisions of Section 1797m-1020.

The petitioner and the Chicago, North Shore and Milwaukee Railroad and the Milwaukee Northern Railway Company, operate single trolley electric systems in the City of Milwaukee. The petitioner asserts that the City of Milwaukee, the Milwaukee Gas Light Company, the Wisconsin Telephone Company, the Western Union Telegraph Company, the Milwaukee and Lake Superior Telegraph Company and possibly other persons, firms or corporations who own, maintain and operate certain sub-surface metallic structures in the streets in the City of Milwaukee; and that from time to time the petitioner company has provided means and equipment to mitigate the injury to these underground structures by electrolysis.

The petitioner desires further in view of expressed complaint concerning the company's methods that an investigation be made by the Commission, or that one be made by order of the Commission, of the electrolysis conditions maintaining on the sub-surface property of the companies mentioned, and of the adequacy of the means adopted by the petitioner for the prevention of the said electrolysis and that rules and regulations be prescribed for the purpose of preventing unreasonable interference between the service of the petitioner and that afforded by other public service corporations of the municipality operating underground structures in the City of Milwaukee.

The hearing on the above matter was held at the City Hall in the City of Milwaukee, on June 13, 1918, at 11:00 a. m. Representatives of the following utilities whose property was affected were present: The Milwaukee Gas Light Company, the City of Milwaukee, the Wisconsin Telephone Company, the Western Union Telegraph Company, the Milwaukee Northern Railway Company, Postal Telegraph Company, the Chicago, North Shore and Milwaukee Railway and the Milwaukee Electric Railway and Light Company. The testimony offered consisted largely of a general statement by Mr. G. W. Van Derzee of T. M. E. R. & L. Co. on electrolysis, its cause and the various methods of mitigation together with a statement on what had been done by them to relieve the conditions as they developed. From this statement it appears that aside from the uninsulated return feeders which amounted to approximately 20 miles of cable and 10 miles of Edison tube, insulated feeders have been installed amounting in value to $114,000. For experimental work the 20th Street station had been arranged for three-wire operations during the peak load at a cost of about $1,500.

It was shown also that the plans of the company contemplated the installation of considerable more one and two million C. M. insulated return feeders.

These statements make it plain that the electric company has had intimate knowledge of the conditions and has made much progress toward the application of the remedies necessary for the prevention of electrolysis.

The hearing resulted in an understanding that the Commission would conduct a survey of the Milwaukee electrolysis conditions, supervised by a representative of the Bureau of Standards, and that the order would be withheld until this work was completed.

In accordance with this arrangement, at a meeting held in Milwaukee August 6, a temporary committee was elected consisting of one of the engineering staff of the Commission as its representatives and one member from each of the utilities interested. At this meeting it was arranged to carry on the survey and that the expense was to be shared by the companies joining in the survey, excepting the City of Milwaukee in such proportion as should be decided by the Railroad Commission.

Mr. E. R. Shepard of the National Bureau of Standards was enged to superintend the work which was carried to completion about e middle of September, 1918.

The survey conducted by the Commission and carried out under e supervision of the Bureau of Standards was more extensive and mprehensive than had ever been attempted in any past investigans.

The following observations were made with smoked chart rerding voltmeters:

21 Overall potential measurements on the tracks.
172 Track gradient measurements.
230 Potential difference measurements between water hydrants and tracks.
35 Measurements of current flow on insulated negative feeders.
14 Measurements of current flow on water pipes.

Potential measurements between cable systems and other strucures were made indicating voltmeters as follows:

Wisconsin Telephone Company's cables	190 locations
T. M. E. R. & L. Co.'s cables	94 locations
City of Milwaukee cables	70 locations

The Western Union and the Milwaukee & Lake Superior Teleraph Companies conducted their own surveys and submitted them or consideration along with the foregoing data.

Several electrolysis surveys were made in the years past and vere of great value in bringing to light, areas in which damage was n progress, and in stimulating the electric railway companies to orrect bad conditions. Five such reports made in 1906, 1910, 1911 nd 1915 were on hand for use in connection with this survey and or comparison of results.

Each of the pipe and cable owning companies submitted a list f failures attributed to electrolysis which had occurred in recent ears and these reports were examined and the analysis of the failures indicated that in a number of instances these failures occurred n localities which it is reasonable to believe have been free from lectrolytic action. This leads to the assumption that soil conditions n Milwaukee, in certain localities are the real cause of some of the ilures.

A comparative system of drainage exists among the different pipe and cable owning companies whereby each company has its own system of drainage worked out with the view of protecting its system and having no undue regard for the dangerous conditions set up by over-drainage in any of the other systems which was also found to be the cause of some failures.

The following tabulation of rail gradient measurements of this survey compared with a similar survey made in St. Paul and Omaha, shows that the conditions in Milwaukee compare very favorably with other large cities.

City		No. of Gradients Measured	Average Gradient Volts Per 1000 Ft.	Exceeding 0.5 Volt Per 1000 Ft. No.	%	Exceeding 1.0 Volt Per 1000 Ft. No.	%
Omaha,	1916	55	0.55	22	40.0	8	14.5
St. Paul,	1917	81	0.47	28	34.6	7	8.7
Milwaukee,	1918	172	0.37	42	24.4	6	3.5

The results of the potential measurements between rail and other underground structures as given in the following summaries also indicate generally good conditions.

The potential measurements from water pipe to rail for a total of 230 locations gave only 32 readings over one-half volt positive and 11 readings of over 1 volt positive to the rail.

The potential measurements from Wisconsin Telephone Company cables to rail for 110 locations gave only five readings over 0.5 volt positive to the rail.

The potential measurements from T. M. E. R. & L. Co. cables to the track for 66 locations gave no readings over .5 volt positive to the rail.

The potential measurements from the city cables to the track for 51 locations gave only 5 readings over .5 volt positive to the rail.

Potential measurements between the different cable and pipe systems also showed the effect of unequal drainage on adjacent systems and the necessity of co-operation of the different interests in working out a more unified system of drainage for all the underground structures.

The drainage current measurements on the Wisconsin Telephone Company cables show very low values due to the great number of drainage points and to the fact that the drainage points are selected at predetermined low potential points and to the low rail gradients. There are 21 drainage points on this system and the maximum hourly average obtained from any one wire was 51 amperes.

The drainage current measurements on drains to the gas and water mains showed a maximum hourly average of 29.7 amperes from any one of nine drains located at the different stations. Five other current measurements on mains showed only a maximum hourly average of 10 amperes indicating that the pipes were carrying a very small amount of leakage current; however, this cannot be considered a representative number of pipe locations.

The foregoing data, the reports of other surveys made as noted, and other sources of information and observations furnished the basis for the following facts:

Considerable electrolysis of water and gas mains and services occurred in early years principally in the vicinity of the Oneida Street station which for a time was the only source of railway current in the city, and in the vicinity of 27th and Chestnut Streets. An attempt was made to mitigate this trouble by bonding the water mains to the railway return circuit at a number of points. Damage to underground structures has continued but in recent years has been much less severe than formerly. The Clinton Street Substation district is the one most seriously affected at the present time. Gas service pipes have been damaged in some locations by discharge of current to drained cable systems with which they come in close proximity.

Up to the year 1900 the only existence of other protection than bonding of rails was a connection between water pipes and the negative bus made in 1893 in the region of the Oneida Street powerhouse.

Between 1900 and 1912 the railway company installed upward of 350,000 pounds of bare negative cable to supplement the rail return. This copper was connected in parallel with the tracks and was very effective in increasing the conductivity of the return circuit and in shunting open rail joints of which there had been a large number. Electrolysis conditions were somewhat improved by the installation of this copper.

Since 1912 the railway company has installed about 420,000 pounds of copper as insulated negative feeders, most of which is in the form of lead-covered cable in ducts. A large part of this copper was installed in 1916 and 1917 and some feeders were not connected until September 1918. In 1917 the 20th Street substation was converted for three-wire operation and has since been operated in that manner during the morning and evening peaks.

These various mitigative measures together with some supplementary pipe and cable drainage have greatly improved electrolysis conditions in all areas. Track gradients and overall potentials of underground structures have been reduced to reasonably low values and the additional protection required for the pipes and cables in some districts can be secured by careful co-ordination of drainage systems and other auxiliary means which may appear desirable from time to time.

The electrical condition of the tracks is by no means satisfactory. Recent tests of bonds made by the railway company reveal a great number of defective joints, particularly in the southern part of the city. During 1918 about one-half of the city system was gone over and some 4,500 defective joints repaired. This work was accomplished under a special bonding program initiated by the company and to be continued till this work is caught up.

The results of this survey indicate that the electrolysis conditions in Milwaukee are comparatively good and that the present system of mitigation is principally responsible for this condition. We feel, however, that certain improvements can be made which may be best determined by continuing this survey and while it might be possible to lay down definite limits of track gradient, over all potentials, voltage from pipe to rail, rail bonding, etc., which would be proper under present conditions, it would be impracticable to lay down definite limits which would be proper as well for the present and also for the future with the changing conditions which are sure to come.

We believe that this matter could be much more effectively handled by a permanent committee consisting of representatives of all the interested utilities who should preferably be resident engineers acting under the jurisdiction of the Railroad Commission, this committee to continue taking the necessary observations and tests to check the conditions periodically and prescribe such changes, etc., as are needed to maintain proper conditions and to submit a report of these observations to the commission on suitable standard form to be adopted by the committee. At least one general report on the electrolysis condition should be sent to the Commission in December of each year, as well as copies of all minutes of the meetings of the full committee.

In view of the foregoing recommendations and in consideration of the jurisdiction of the Commission in this matter, it is desirable to have the Commission represented on this committee by some one from the engineering staff as an ex-officio member so they may be kept in close touch with the work.

THE MILWAUKEE ELECTRIC RAILWAY AND LIGHT CO.
Public Service Building
Milwaukee, Wisconsin

August 27, 1919.

Mr. H. P. Bohmann, Supt.,
Milwaukee Water Department, Milwaukee, Wis.

Dear Sir: At the suggestion of Mr. R. B. Brown, Chairman of the Milwaukee Electrolysis Committee, we are forwarding herewith a blueprint showing in red certain extensions and additions to the insulated negative railway return system which we contemplate installing in the City of Milwaukee. The work we propose doing around the various stations is as follows:

20th Street Station:

Most of the load carried by the 20th Street Station is west of the station and the losses in the return circuit would be reduced and electrolytic conditions would be improved by putting in more copper. We propose to install three additional 1,000,000 c. m. cables, one terminating at Fond du Lac Avenue and 27th Street, one terminating at 35th Street and North Avenue and the third at 27th and Walnut Streets.

Commerce Street and Oneida Street Stations:

We propose to install a 1,000,000 c. m. cable from the Commerce Street Power Plant to 7th and Walnut Streets, a 2,000,000 c. m. cable from the Oneida Street Plant to 8th and Wells Streets, a 2,000,000 c. m. cable from 8th and State Streets to 12th and State Streets, a 1,000,000 c. m. cable from West Water and Sycamore Streets, to West Water and Fowler Streets, and a 1,000,000 c. m. cable from East Water and Michigan Streets to East Water and Detroit Streets.

The additional cable running west from Oneida Street is made necessary through the installation of additional load at the Milwaukee Western Fuel Company at their 16th Street Yard. It is proposed to install resistances between the insulated negative return cable and rails at West Water and Sycamore Streets and at East Water and Michigan Streets.

Burnham Street Substation:

In the near future we contemplate the building of a substation on the north side of Burnham Street west of 26th Avenue, and propose to install as insulated negative return feeders a 1,000,000 c. m. cable running west to 36th Avenue and a 1,000.000 c. m. cable running north on 26th Avenue to National Avenue. This cable would tap the rails also at 26th Avenue and Greenfield Avenue.

The purpose of forwarding this information to you is to acquaint you with the work to be done so that you will be in position to discuss the matter at a meeting of the committee which Mr. Brown expects to call in the near future.

Yours very truly,

(Signed) G. G. POST,
Electrical Engineer.

PART XVII

COMMENT ON REPORT MADE BY THE NATIONAL BUREAU OF STANDARDS IN NOVEMBER, 1918

FOR RAILROAD COMMISSION OF WISCONSIN, RELATING TO ELECTROLYTIC CONDITIONS IN THE CITY OF MILWAUKEE

By E. E. Brownell

The report made by the National Bureau of Standards to the Railroad Commission of Wisconsin, showing electrolytic conditions in the City of Milwaukee, Wis., is dated November, 1918, but amended on June 7, 1919.

The original report was but a typewritten one. The writer has printed the same in 97 pages, not including 14 tables, 9 maps and 4 illustrations. Only 2 illustrations out of 4 were reproduced, as the others were of no importance.

The following statements and comments are made by the writer upon this report: (All references made are to the printed page numbers, and not to the original typewritten page numbers.)

1. This electrolytic survey was made under the authority of the Railroad Commission of the State of Wisconsin, against a vote of 28 to 8 by the Milwaukee City Council requesting the National Bureau of Standards not to come to the City of Milwaukee. (See page 3 of the Bureau of Standards printed report.)

2. There were 21 overall measurements on the tracks.

172 Track gradient measurements.

230 Potential difference measurements between fire hydrants and tracks.

35 Measurements of current flow on insulated negative feeders.

14 Measurements of current flow on water pipes.

These electrical measurements were made by means of 120 pairs of wires belonging to the Wisconsin Telephone Company, and they were recorded by means of smoke-chart recording voltmeters.

The accuracy of these electrical readings is very seriously questioned, considering the high electrical resistance of the telephone leads and the insensibility of these recording voltmeters for low potential registration. The writer believes that the electrical readings noted upon Plates 2, 3, 4, 5 and 6, facing pages 38 and 52 of the printed report, do not correctly represent the true electrical state of affairs.

3. On pages 3 and 4 of the printed report, the National Bureau of Standards attempts to interpret ancient electrical information of The Milwaukee Electric Railway and Light Company, together with electrolytic surveys beginning in 1910 and ending in 1915, to draw their conclusions of past electrolytic conditions. Prior to the year of 1910 their conclusions are all guess work, as their data is based solely upon generalities.

4. The National Bureau of Standards, page 4, leaves the impression that from 1900 to 1912, a total of 350,000 pounds of supplementary rail return cables were installed. They do not differentiate between supplementary track negatives and requisite rail connections. From 1912 to 1918 they claim that 420,000 more pounds of supplementary feeders were installed, making a total cost of over $114,000.00 for insulated negative return feeders. The above statements are intended to say one thing but mean another.

Most of the above copper cables would have been installed, irrespective of electrolytic conditions in the City of Milwaukee.

5. On page 5 of the printed report, under heading of "Summary of Recommendations," the National Bureau of Standards recommends the installation of the "Pipe Drainage System"; also that certain connections upon gas and water piping systems should be made with drainage copper wires.

6. The National Bureau of Standards fails to state the number of metallic connections now in use in the City of Milwaukee, between gas, water and lead-sheath covered cables and copper cables of the return circuit of The Milwaukee Electric Railway and Light Company; neither do they recommend that any of them be changed or enlarged.

The writer is of the opinion, that many of the copper connections made to the Milwaukee Water Works System, beginning in 1893 and continued for many years thereafter, were improperly installed and without the knowledge or approval of the City of Milwaukee.

7. The National Bureau of Standards, never took an electrical reading in the City of Milwaukee until 1918, and for this reason has no right to even venture a guess as to the amount of electrolytic damage upon the distributing system of the Milwaukee Water Works.

8. In 1893 Mr. O. M. Rau installed an electrolytic mitigating system by connecting water pipes to rails. This was only three years after the starting of the first electric street car in Milwaukee in April, 1890. Mr. Rau had charge of the return circuits of the Milwaukee Street Railway and The Milwaukee Electric Railway and Light Company from 1893 until about 1899. In 1900, 1901, 1902, and 1905 E. E. Brownell made Electrolytic Surveys in the City of Milwaukee and found conditions anything but satisfactory. Then came C. R. Pierce in 1910, Ray Palmer in 1911, Pierce-Schulte-Burgess in 1912, Frank K. Brainard in 1915 and E. E. Brownell again in 1917.

9. The writer is firmly convinced that electrolytic conditions in the City of Milwaukee, upon the Milwaukee Water Works system, have been menacing and serious from 1900 to the present day (1919), with possibly an equally or more serious condition from 1890 to 1900. The National Bureau of Standards attempts to reason that the present destruction on the Milwaukee Water Works is due entirely to old unmitigated electrolytic conditions.

10. The tremendous electrolytic depreciation upon the Milwaukee Water Works system is due to past and present menacing electrolytic conditions. These conditions were known to be menacing by the electric street railway companies for the past 27 years, according to their own admission and evidence that the writer has personally obtained since 1900.

11. The National Bureau of Standards has assumed without warrant that, with certain electrolytic mitigative measures adopted as recommended by them, electrolytic conditions in the City of Milwaukee will be better than in any other large city in the country where a grounded return railway current is employed. Yet with one or two possible exceptions, they never made an Electrolytic Survey in a city larger than Milwaukee.

12. On page 7 of the printed report of the National Bureau of Standards, it is stated that five-tenths (.5) of a volt difference of electrical pressure between water pipes and rails is generally considered safe. This is the wildest statement made by the National Bureau of Standards in their 1918 report.

On June 7, 1919, seeing what a ridiculous mistake they had made, they recalled the assertion. (See pages 1, 2 and 3, as appended to the 1918 printed report of the National Bureau of Standards.)

13. The 6-inch c. i. water main on Maple Street, near Clinton Street, Milwaukee, was electrolytically destroyed under an average difference of electrical pressure between water main and rails of .55 of a volt which was admitted on Plate 8 as the true average electrical reading in their 1918 printed report.

This 6-inch c. i. water main was laid on September 5, 1884, and part of it taken up by E. E. Brownell in March, 1918. The maximum difference of electrical pressure in 1900 was 1.2 volts and the average about .5 of a volt between water main and rail.

16. This is only one of many instances where the National Bureau of Standards has reversed its opinion and conclusions.

On page 7 of its Springfield, Ohio, report, dated February 1, 1914, the National Bureau of Standards recommends that NO metallic connection be made between pipes and the railway return circuit. Four (4) years later they recommend them (1918), and on June 7, 1919, the Milwaukee Gas Light Company objects to their use.

17. On page 11 of the printed report the National Bureau of Standards gives 1906 as the date on which the writer made his first electrolytic survey in the City of Milwaukee. The correct date was August, 1900, or six (6) years earlier.

18. On page 12 of the printed report, they claim the electric street railway began operations in 1891. Operations began April 4, 1890.

19. The reader should not permit dust to be thrown in his eyes, when he reads the 1918 Milwaukee Electrolysis report by the National Bureau of Standards. Notice that in no instance was any mention made as to the resultant physical electrolytic damage to the Milwaukee Water Works system, or the accrued injury.

20. The entire report of the National Bureau of Standards (1918) is so full of hundreds of misquotations, misstatements, irregu-

rities, contradictions and wrong conclusions, that to point out all them would be equivalent to compiling a report in excess of the printed pages. The size of the report has only served to multiply ie innumerable errors of and the ridiculous conclusions drawn by ie National Bureau of Standards.

21. It is really amusing that the Milwaukee Gas Light Cominy should object to the use of the Pipe Drainage System, as an ectrolytic protective measure, when this system has been in use (in me sort of installation) in the City of Milwaukee for the last 26 ars.

22. True it is, that possibly no direct metallic connections may ive been made with the Milwaukee Gas Light Company's piping stem; yet with thousands of metallic connections between the pipg systems of the Milwaukee Water Works and the Milwaukee Gas ight Company, it is equivalent to the same thing. Axiom: things nnected to the same thing are connected to each other.

23. The Milwaukee Gas Light Company's position is similar to ie Wisconsin Telephone Company—Eau Claire Street Railway Cominy case in 1890. Both were violating the law. With the Milwaue Gas Light Company's late pipe line construction, it is a serious iestion, as to whether or not they themselves have been careless id negligent through installing insulated pipe joints. This is the ason why Mr. R. B. Brown, General Manager, Milwaukee Gas ight Company and Chairman of the local "Electrolysis Committee," opposed to the use of the Pipe Drainage System in any form, alıough it has been used for the last 26 years in Milwaukee. There no carelessness on the part of the Milwaukee Water Works along is line.

24. The Wisconsin Telephone Company have used the Pipe rainage System since the installation of their first underground, ad-sheath, covered cable. This is equally true with respect to The ilwaukee Electric Railway and Light Company, as applied to their ad-sheath covered, underground, copper cables.

25. On page 16 of the printed report of the National Bureau of tandards, it is claimed that the only mitigative measure adopted rior to 1900 was a connection between the negative busbar and water ipe line in front of the powerhouse. Mr. O. M. Rau's report of 1893 ys that about 57 metallic connections were made between water ipes and rails; after over 200 such connections were discovered by

Mr. G. H. Benzenberg in 1892. These were made without the knowledge and consent of the City of Milwaukee.

26. On page 93, item No. 9, there will be found a recommendation by the National Bureau of Standards, in the 1918 printed report, for a permanent local "Electrolysis Committee" for the Milwaukee district. This plan may be feasible between public service corporations, privately owned and operated, but a municipality should never join in such an impractical scheme, as will be explained later in this report by the writer.

RECOMMENDATIONS AND CONCLUSIONS

After reading the report of the National Bureau of Standards, dated November 26, 1918, and amended June 7, 1919, as made to the Railroad Commission of Milwaukee; together with the writer's knowledge upon the subject, the following recommendations are made and conclusions drawn:

1. The Milwaukee Electric Railway and Light Company is operating its electric street railway system contrary to its original franchise requirements, as well as in violation of the laws of the State of Wisconsin. (See copy of Act on pages 32 and 33 of the Compilation Section of this report).

2. There are no legal means by which most of the damage amounting to hundreds of thousands of dollars through electrolytic destruction to the distributing system of the Milwaukee Water Works, can ever be recovered.

3. Every legal and moral effort should be made on the part of the City of Milwaukee to arrest further electrolytic deterioration on the system of the Milwaukee Water Works. This is very imperative.

4. There are two ways to accomplish a practical immune electrolytic result. One is by a legally drawn and properly executed contract between the City of Milwaukee and The Milwaukee Electric Railway and Light Company, the Milwaukee Northern Railway Company and the Chicago, North Shore and Milwaukee Railroad Company. The other is through the requisite legal proceedings, either in violation of franchise requirements, or under the Wisconsin laws.

5. As The Milwaukee Electric Railway and Light Company has refused to agree to be bound by any form of a written contract between it and the City of Milwaukee, except to agree to do such elec-

trolytic mitigative installation as was satisfactory to the National Bureau of Standards, it is useless to consider further a contract by amicable adjustment, as they will not commit themselves in writing.

6. Under no circumstances whatsoever should this subject be handled, except under a definite form of contract, binding and obligatory upon The Milwaukee Electric Railway and Light Company, or under a court order compelling them to do something specific and stated fully in unquestionable language.

7. For the City of Milwaukee to agree to bind itself by the findings and judgment of the National Bureau of Standards, without any written agreement with The Milwaukee Electric Railway and Light Company, would be the height of foolishness.

8. In the writer's opinion, the National Bureau of Standards report, is, either ignorantly or knowingly, decidedly and unreasonably unfair to the best interests of the City of Milwaukee. One would think from their 1918 report, that they were the paid representatives of The Milwaukee Electric Railway and Light Company, instead of representatives of a Department of the United States Government.

(There has always been an air of mystery in connection with Mr. E. R. Shepherd's original visit to the office of Mr. Clifton Williams, City Attorney, in the early part of 1917. Who sent him to see Mr. Williams?)

9. Electrolytic depreciation upon the distributing water system of the Milwaukee Water Works is a "Property Damage" and having no direct relation to service or rates, should be handled by the local authorities of the City of Milwaukee, as such property injury.

10. Irrespective of the franchise obligations, Wisconsin State law and the Wisconsin Railroad Commission, the City of Milwaukee undoubtedly has, under its police powers, the requisite authority to protect its most valuable physical property against electrolytic deterioration, so far as the same can be done within the bounds of right and reason.

11. As the City of Milwaukee owns and operates the Milwaukee Water Works, it should be the only party to have any right to pass upon the electrolytic protective features. If it is unreasonable, The Milwaukee Electric Railway and Light Company can legally object and present the case upon its legal merits.

12. The writer has the highest possible admiration and respect

for the integrity, ability and equity of our courts. With the facts properly presented before them, there need be no fear of being imposed upon by unscrupulous public service corporations.

13. On February 28, 1918, the City Council of Milwaukee voted 28 to 6 to have the City Attorney litigate the question of electrolytic deterioration upon the Milwaukee Water Works.

14. The Milwaukee Electric Railway and Light Company obtained the consent of the Railroad Commission of Wisconsin to have it investigate the Wisconsin Statute Sec. 1797m-1020, and further requested from the Railroad Commission of Wisconsin that the National Bureau of Standards make the Electrolytic Survey in the City of Milwaukee.

No greater insult could have been delivered to the municipal authorities of the City of Milwaukee, than this apparently clever move on the part of The Milwaukee Electric Railway and Light Company.

Neither could the National Bureau of Standards have found a better way of showing which way its sympathy ran.

15. In regard to the creation of a local "Electrolysis Committee" for the promotion of better electrolytic conditions in the City of Milwaukee, as recommended by the National Bureau of Standards, it is too illegal and impractical to receive any serious consideration.

16. What chance would one city representative have, on a local Electrolysis Committee with representatives of about eight different public service corporations? None. Public service corporations are of one class; that is, to operate for the largest monetary return. A municipal utility is for the best interests of the citizens. What a contrast! Yet it is proposed to have such a committee pass unselfishly upon this question of Electrolysis. Impossible!

17. Whatever is done upon the electrolysis question in the City of Milwaukee should be done through the proper municipal channels, and not promiscuously. The subject is entirely too vital for anything but legal and practical methods taken under municipal authority with the consent and approval of the City Council of Milwaukee, the representative body of the City of Milwaukee. No other way should be considered.

18. While Mr. Henry P. Bohmann may only be an interested party in the newly formed local Electrolysis Committee, he is there

for the purpose of showing a proper respect to the Railroad Commission of Wisconsin and to the other public utility corporations operating in the Milwaukee District, and after consultation with the City Attorney, Mr. Henry P. Bohmann, Superintendent of the Milwaukee Water Works, agreed to attend the meetings of the so-called "Milwaukee Electrolysis Committee," not as a representative of the City of Milwaukee, but as a representative of the Milwaukee Water Works.

19. Mr. Bohmann's presence at the few meetings of the Electrolysis Committee is in no way binding upon the City of Milwaukee and was so recognized by all parties because he had received no authority from the Common Council to represent the City of Milwaukee at these conferences, and he merely attended these meetings as an operating man interested in keeping in touch with the local electrolysis situation.

20. It is my opinion that these electrolysis committee meetings will result in nothing of any value for reasons stated heretofore and subsequently herein, and it is my personal opinion that for these reasons Mr. Henry P. Bohmann should not further continue to attend the meetings of this committee because it is now my opinion and recommendation that the proper procedure from this time on is vigorous litigation, and his further presence at these meetings might embarrass the City Attorney in said litigation.

21. In fact, from all that the writer can learn, there is not an individual on the local Electrolysis Committee who is sufficiently technically versed to pass intelligently upon this subject. Even Mr. Arthur Jeremiah Sweet, Electrical Engineer, The Milwaukee Electric Railway and Light Company, never had any practical experience outside of the City of Milwaukee, and very little in the City of Milwaukee. As a Cornell University graduate of June, 1901, he should have been better posted upon the subject of electrolysis.

22. The American Water Works Association, the American Gas Light Association, the National Electric Light Association, Natural Gas Association, the American Railway Engineering Association and then the combined American Committee on Electrolysis have all (from 1893 to 1919) made great efforts to standardize the technic of electrolytic investigation and mitigation, but up to the present time nothing substantial has been accomplished by them.

23. As most of the American Water Works systems are owned and operated by municipalities, it would be practically a physical impossibility to get the hundreds of cities to agree upon a matter in which the prevailing condition is "Property Damage." Local and legal conditions prevent any such combined form of procedure.

24. The National Bureau of Standards' local "Electrolysis Committees" throughout the United States have not in one single instance perfected a practical, legal and operative organization. They are

only preliminary assemblies of individuals without authority even to bind their principals on any feature of the subject.

25. The proper solution of the subject of Electrolytic Deterioration is through the active pursuit of the matter in the field, and not in conventions, committee parlors, associations' rooms and institute chambers, sitting in easy chairs through many long drawn out discussions. The great American, Thomas A. Edison, says nothing was ever accomplished by him through inspiration, it was by "Perspiration." This applies equally well to the Electrolysis question.

26. In no other instance on record or within the personal knowledge of the writer, has any State Commission assumed jurisdiction on the subject of electrolytic deterioration and mitigation. The Railroad Commission of Wisconsin in the City of Milwaukee case is the first exception to this rule. Neither is there any record of a State Commission asking the National Bureau of Standards to make an electrolytic survey for them in a city of that state.

27. With all due respect to the sovereign rights of the State of Wisconsin, through the Railroad Commission of Wisconsin, the writer is thoroughly convinced that it is making a great mistake to undertake to investigate, regulate and control the electrolytic conditions in the City of Milwaukee. The great mistake (in principle) made by the Railroad Commission of Wisconsin in the Beloit, Wis., electrolytic mitigation shows how easily a State Commission can be mislead in this matter. The representative of the Railroad Commission, in the Beloit case, may have had the best intentions in the world, but was grossly ignorant of what he was doing, in following blindly the teachings of the National Bureau of Standards without personal knowledge of the subject matter.

28. Every municipality, large and small, in the United States to be thoroughly American, should have the right and privilege of making requisite local rules and regulations, within its constitutional limits, that are most applicable and equitable to the welfare and protection of its citizens. To divest a municipality of its police power, common law rights and home rule, is un-American and removes the true incentive which must prevail if that community is to be progressive. No one knows the local conditions like those who are taxpayers and who live and pursue their respective vocations in that community. It spells disaster to be governed wholly by State or Government authorities.

29. For instance, no District, State or Government body could have built and managed the Milwaukee Water Works like the local

municipal authorities, as they knew what they wanted and paid for it themselves. This is true civic pride, the foundation of our great American Government.

30. The City of Milwaukee has no direct interest in the manner in which the menacing electrolytic conditions in Milwaukee should be eliminated, so far as constructional features are concerned. The City of Milwaukee cares nothing about track gradients, number of substations, powerhouses and the like, as these are indirect conditions.

31. The City of Milwaukee owns and operates a valuable water works system, and it is vitally interested in getting those who are slowly, but surely, destroying vast portions of it, to so operate as not to cause any further appreciable electrolytic injury to it.

32. The writer admits that even with the single trolley systems the requisite electrolytic immunity can be obtained and at a comparatively reasonable cost with the proper electrical engineering ability.

33. Electrolytic immunity would mean to make and maintain the Milwaukee Water Works distributing system electrically negative to tracks, and so far as it is practically possible, electrically negative to the surrounding earth. The writer firmly believes that both of these immune electrolytic conditions can be met, practically, in the City of Milwaukee by the three electric street railway companies without undue hardship to any or all of them.

34. The writer would most earnestly and sincerely advise the City of Milwaukee against any verbal committee arrangement and adjustment made outside of the legal and administrative bodies of the City of Milwaukee. Even then everything should be made in writing, stating the proposed electrolytic conditions to be guaranteed by the local electric street railway companies, directly applicable to the Milwaukee Water Works distributing system; all electrolytic mitigations and construction to be paid by the parties causing the injury.

35. Furthermore, the City of Milwaukee should have the right under any ordinance, contract or legal order of Court, to employ a skilled consulting electrical engineer, at the expense of the electric street railway companies, to see that such guaranteed immune electrolytic conditions are complied with under any such arrangement legally made between the City and the electric street railway companies.

36. The writer is thoroughly convinced, knowing the evasive-

ness of The Milwaukee Electric Railway and Light Company, that nothing short of litigation by the City of Milwaukee will ever bring about satisfactory immune electrolytic results. This is particularly true so long as the North American Company of New York and the present local staff of The Milwaukee Electric Railway and Light Company continue to own, operate and control the local electric street railway system of the City of Milwaukee. This is a heartless, privately owned public service corporation and regardless of the rights and privileges of the citizens of the City of Milwaukee. They are not accountable for much that they have done, as they really know no better than to satisfy their greedy ambitions.

37. The fundamental principles upon which a privately owned public service corporation is operated being diametrically opposite to those of a municipal public service institution, it is impractical and very inconsistent to have both considered alike, and especially upon the subject of electrolytic deterioration.

38. Every municipality should have a certain amount of authority in the regulation, control and operation, of privately owned and operated public service corporations. This will insure stability and maximum service at minimum cost. No public service corporation should interfere with the operation of a municipal institution, except as a taxpayer and as a voter. Therefore, the municipality should be the controlling factor in every such community and should be the one to take and maintain the initiative in the matter of electrolysis.

39. No American city of its size, considering the public service corporations as a whole, has received such poor utility service and had so many millions of dollars taken out of the city, as has the City of Milwaukee. The Milwaukee Gas Light Company is the best of them all, as they have given fairly good service, but at a price well above the equitable line. The Wisconsin Telephone Company, being a child of the greatest octopus on the face of the earth, has never shown anything but selfishness.

40. The writer can easily see numerous complications, all of which would be to the disadvantage of the citizens of the City of Milwaukee, to come from joining in a local "Electrolysis Committee." The City of Milwaukee would have everything to lose and nothing whatsoever to gain by doing so. It is equivalent to asking the eight different public service corporations of Milwaukee to assist in the management of the Milwaukee Water Works.

41. How violently any one of these eight privately owned public service corporations would remonstrate if the City of Milwaukee

should attempt to actively manage any one of their physical properties. They would be before the Milwaukee City Council, Railroad Commission of Wisconsin or in the Courts within a few hours, with protestations galore.

42. The sovereign right of the State of Wisconsin, through the Railroad Commission of Wisconsin, and a Department of the United States Government should not be permitted to alter the complexion of the Milwaukee electrolysis situation, because both of them have assumed an improper position toward the City of Milwaukee.

When the laws of the State of Wisconsin have been amended, so as to divest the municipalities of their local rights and privileges, there is then time enough to turn over the electrolysis situation to the Railroad Commission of Wisconsin.

43. The writer is a firm believer in system and organization, through the proper channels, and especially in municipal matters, and for this reason is against the participation of any municipal representative in the local "Electrolysis Committee" plan. To do so, would not be for the best interests of the City of Milwaukee, as this committee is not a properly constituted body in any sense of the word. How could such a body ever be of any real value to the City of Milwaukee without having definite authority from either the administrative or legislative body of the City of Milwaukee?

44. The electrolysis problem in the City of Milwaukee, as affecting the distributing system of the Milwaukee Water Works, should be solved as any other property damage proposition. Whatever is done, should be done by due process of law and upon good businesslike principles, and not left to verbal understandings (or misunderstandings) between individuals, committees, commissions or the National Bureau of Standards. The latter may change its mind over night, or to suit the wishes of some disgrunted public service corporation, as it did on June 7, 1919, for the Milwaukee Gas Light Company. The City of Milwaukee will rue the day that it permits any procedure not founded on principles of law and sound business.

45. No municipal legal department in the United States is better qualified to protect the rights of its citizens than the Milwaukee Legal Department. It has few equals and no superior in abilty, integrity of purpose and untiring faithfulness to duty.

The Milwaukee City Council on February 28, 1918, showed its unlimited faith and appreciation of the legal department, when it voted 28 to 6 to litigate the question of electrolysis. (See File No. 13740.)

46. The chief reason why electrolytic conditions, in most of our American cities, have not been properly mitigated, is because of the failure to place the subject upon a definite and business-like basis and lack of understanding of its importance.

47. The National Bureau of Standards' record shows that it has never settled, amicably or otherwise, a single electrolysis case upon a definite basis to the satisfaction of those concerned, but has left the question open for endless disputes. It should be noted by the reader, that Congress makes the appropriations of nearly $500,000 for the National Bureau of Standards to spend annually.

48. The writer believes in litigation only as a last resort in properly settling the question of electrolysis. In the case of the City of Milwaukee there appears to be no other alternative. The earlier this litigation is begun the greater will be the benefits derived by the City of Milwaukee, as nothing can be gained by delay. It would be a crime to permit this valuable property (Milwaukee Water Works) to suffer still greater physical injury than it has already sustained. It would be unfair to the citizens and taxpayers.

How different it would be, if the City of Milwaukee, through home rule, could participate in the regulation and control of the Milwaukee Electric Railway and Light Company. It will have to do it some day.

50. In conclusion, the writer conscientiously feels that his sincere efforts, on behalf of the City of Milwaukee, to get The Milwaukee Electric Railway and Light Company to amicably and equitably adjust this important matter, have been met with not only unethical and unfair treatment, but with a spirit of willful revenge against the writer and the City of Milwaukee (administration), because both sought to protect the citizens of Milwaukee against unwarranted imposition and rank injustice.

The writer wishes to acknowledge, with full appreciation, the unlimited confidence and respect shown him by the various branches of the city government of the City of Milwaukee.

Respectfully submitted,

Consulting Electrical Engineer.

September 1, 1919.

INDEX

TO

PERSONAL MENTION OF INVENTORS, AUTHORS, ENGINEERS, PROFESSIONAL, MUNICIPAL AND PUBLIC UTILITY PEOPLE

PAGE
Abbott, A. V. 135
Adams, C. F. 61
Adams 137-154
Ahlborn, G. H. 267
Alldridge, Alderman 295-300
Alldridge, Aldeman 295-300
Alleman, Dr. Gellert 145-146
Allen, John S. (commissioner) 249-252
Allis 174
Allis, Edwin P. 15
Allyn, H. A. 120
Altpeter, Alderman 298-300
Ampere 55
Anderson, L. C. 149-223
Arnold 23
Arnold, Bion J. 147
Arogo 55
Aryton, W. E. 22

Bailey, W. W. (Congressman) 270
Baylies, O. S. 210
Baldridge, Thos. J. (Judge) 270
Barrett, John P. 137-154
Bartling, H. N. 118
Baumann, Alderman 295-298-300
Becker, Washington 93
Beggs, John I. 118
Bell, Dr. 123
Bentley, E. M. 61-73
Benzenberg, George H. 16-97-98-103-104-121-144-145-322
Bertin 21
Bigelow, F. G. 240
Billings, A. W. K. 75
Blair, E. J. 147
Boehm, F. J. 308
Bogk, Alderman 298-299-300
Bohn, Alderman 298-299-300
Bohmann, Henry P. 13-17-104-258-315-324-325
Bologna 21
Brainard, Frank K. 118-319

Page

Braman, Percy 13
Brigden, W. W. 149-154
Briggs, H. E. 103-117
Brodhead, E. H. 14
Brown, Harold P. 127-128-154-222-224
Brown, R. B. 315-321
Brown, W. R. 103-117
Brownell, E. E. 116-118-127-128-154-213-222-223-224-226-245-256-260-261-262-263-264-265-266-267-268-270-271-272-273-278-279-317-319-320
Brush 21
Budd, Britton I. 216-217
Bulder, Alderman 298-300
Burgess, Prof. C. F. 117-140-141-319
Burnham, George 14
Burnham, Philo G. (Notary) 273
Burch, Edward P. 195
Butler, H. L. 210

Caldwell, Prof. F. C. 183
Campbell, Alderman 298-300
Carter, (Judge) 225-226
Caulfield, John C. 144
Chase 174
Christie 56
Clarke (Judge) 225
Claussen, Oscar 144
Coleman, Alderman 295-298-300
Cook 170-171-173-175
Corcoran, President Council 295
Cotterill, E. B. 240
Cowdery, Edward G. 243-269
Cromwell, W. M. 95
Crosby, Oscar T. 123

Daft, Leo 36-55-61
Dal Negro 22
Davenport, Thomas 22-55
Davis 137
Davis, F. A. W. 104-145-154
Davidson, Robert 22
Dawson, Philip 134-135
Delany, P. B. 184-185
Deprez, Marcel 22
Dexter 246
Doerfler, Alderman 2
Dreisbach, W. Fred (Notary) 2
Dujardin .....

Earl, George G. 2

PAGE
ton, Alexander ... 92
son, Thomas A. ... 22-55-61-71-88-89-93-127-251-326
trom, J. S. ... 186
worth, I. ... 92
ier, Alderman ... 298-300
tein, Alma (Notary) ... 308

iday ... 21-22-55
ner, Moses ... 55
nham, Isaiah H. ... 73-126-127-154-155-167-168-170-171-172-173-174-240
s, Alderman ... 298-300
... 172-173
kell, N. H. ... 258
d, Cyrus ... 55
d, S. D. ... 55-61
ier, Edwin A. ... 141-142
ier, F. E. ... 61
d, F. R. ... 56
es, H. C. ... 156-157-171
s, W. E. ... 143
drich, Alderman ... 295-298-299-300
sche ... 23
nent ... 22
er ... 171-173

ani ... 21
tz, Prof. A. F. ... 138-139-142-264-265-267
dner, L. H. ... 104-145
sheimer, George C. ... 257-258-259
rardi, B. ... 185
dell, J. M. ... 134
mme ... 21
nt, J. H. ... 142
ss, Alderman ... 298-300
y ... 137-155
de, George T. ... 294-298-300
ene, Alderman ... 299-300
gan, Alderman ... 298-300

l, Thomas ... 55
mer, J. T. ... 275
rison, H. E. ... 183-184
ner, Alteneck ... 22
ry, J. C. ... 22-61-73
derson, J. C. ... 94
ing, Dr. Carl ... 23-56-137
rick, Albert B. ... 135-155
rman, Alderman ... 298-300
keth, J. ... 182-183-186
itt ... 137-155

PAGE
Hinckley, F. E. 93-94
Hinsey, J. A. 93
Hoan, Daniel (Mayor) 103-117
Hagar, Director 29
Hopkins, Dr. 36
Hoskins, C. H. 240
Houston, E. J. 22-38-61-62
Howell, Thomas E. 224
Hummell, G. W 95

Jackson, Prof. D. C. 128-130-131-132-133-141-143-155-176-177-178-179-223-243-244-268
Jackson, William (engineer) 108-138-160
Jackson, W. A. (attorney) 299
Jacobi 22
Jarner, J. H. R. (deputy clerk) 221
Jenkins 137-155
Johnson (Judge) 94
Jones (chairman) 187-188
Julien 61

Kennelly, A. E. 137
Kempf, Alderman 298-300
Klies, Alderman 298-299-300
Koch, Alderman 289
Koerner, Alderman 298-300
Knight, W. H. 24-61-73
Knudson, A. A. 135-136-155-258

Lanpher, E. E. 143-144-257
Lee, Fred R. 133-155
Lewis & Fowler 123
Lewis, W. T. 60
Leuch, P. F. (city clerk) 295-298-301
Lochridge, E. E. 276-277-278
Logan, H. K. 261-267-273
Low, G. P. 137
Lukaszenwicz, Alderman 298-300

Mack, E. S. (attorney) 245-252
MacMillan, T. C. 221
Manschott 94
Mansfield, George W. 73-74
Marcus, A. 95
Mathe, Madge (notary) 304
Mather, E. 104-145
Mattern, R. P. 118
Maury, Dabney H. 104-136-145-156-222-223
McCluer, C. E. 234
McCollum, Burton 258-261-263-267-269-273-275-277
McGoegh, Peter 93

PAGE
inley, Alderman 298-299
eod, C. D. 240
lillan, Thomas 15
ighe, Thomas J. 123-125-133

roff, Joseph A. 16
enheimer, Alderman 299-300
e 103
r, Elam 142-143-244-265
r, Noyes & Miller (attorneys) 77
ward, Samuel C. (notary) 262-268
hell, A. 14
an, Alderman 298-299-300
jeua, C. 103
se, Charles H. 73-120-121-137-155-156-241-242-243
loch, Alderman 295-298-300
phy, John Z. 139-146
phy, Herbert S. 146
kat (attorney) 305-308

ns, H. 120-121
baker 137-156
n, T. S. 210

nnor, Alderman 298
ill, Edward 14
tt, Frederick 95
n, Alderman 298-300

t, Frederick 95
notti 22
, Dr. Charles Grafton B. 22-55
ier, Ray 20-103-117-139-140-291-319
er, F. E. 240
e, H. C. 240
son, F. S. 73-120-134
y, W. T. 279
y 22-137-156
rs, E. C. 24
e, Clarence R. 116-117-140-141-319
r, Robert L. 105
er, Charles F. 93-94
er, Guido 14
kinton, John 14
ton, George W. 133
e & Co., J. Morton 94
sch, Charles J. 16
, G. G. 316
am, J. E. 142

PAGE
Radke, Alderman 298
Raley, James 135
Rau, O. M. (engineer) 98-99-100-101-102-103-196-251-319-321
Reynolds, Alderman 298-300
Richey 147
Ritchie 22
Rosa, Dr. E. B. 141-143-244-261-263-268-269-275
Rowland 137-156

Sanborn, A. L. (Judge) 136-219-221
Schieren, Hon. Charles A. 133
Schlesinger, W. M. 61
Schoen, A. 137-156
Schrieber, Martin L. 147
Schulte, W. B. 117-141-319
Seidel, Alderman 298-300
Sever, Prof. George F. 137-156-181-184-185
Shaw, James D. (attorney) 251-252-305-308
Sheldon, Dr. Samuel 137-156
Shepherd, E. R. 281-282-311-323
Short, S. H. 61-72
Siemens, Dr. 21-22-36-37
Simmons, Fred G. 292
Simpson, W. L. 252
Smith, Stuart 134
Sparks 174-175
Sprague, Frank J. 23-36-38-61-62-77-86-126-236
Staal, George 16
Stanton, L. W. 188
Steinmetz, Dr. C. P. 147
Stewart 156
Stillwell, L. B. 181
Stobbart, A. J. (attorney) 144
Stone, Charles A. 156-157-169-171
Stone & Webster 104-108-115-138
Storrs 137-156
Stratton, Dr. S. W. 267-279
Strehlow 295-298-300
Sweet, Arthur Jeremiah 252-299-325
Swinburne, J. 137-156
Szczerbinski, Alderman 298-300

Taft, William Howard 227
Thayer, G. L. 122
Thomas, Thomas 60
Thomas 172
Thomson, Elihu 22-38-61-62
Thompson, Alderman 295-296-297-298-299
True, E. S. 244
Tucker, A. A. 103-104

PAGE
rbanek, Alderman 295-298-300
hlenhaut, Frederick 257

ail, J. H. 134
an Depoele, Charles J. 36-61-72
an Derzee, G. W. 249-250-251-252
an Dyke (attorney) 305-308
illard 93-94-95
ogel, August 94
olta 21
on Hoffman, A. 101

alenn 22
all, E. E. 260-262
alker, George H. 92
arner, R. L. 122
arren, Howard S. 141-142-143-244-268
aterman, Frank N. 142-181-264
ean, Frank L. (Master) 219
eiss, Alderman 298
eston, Dr. Edward 22-282
etmore, Charles W. 95
heatstone 22
heeler, George K. 82
heeler, W. M. 147
ilde 22
illiams, Clifton 249-262-292-294-295-298-299-303-304-323
inslow 171-172-173-174
ittigg, Alderman 298-300
hynkop 137-156
ood, C. V. 277
oodman, Dr. Clarence E. 55-56
yer, Samuel S. 142-264

PART XVIII

MILWAUKEE ELECTROLYSIS SUIT

INTERLOCUTORY COURT ORDER

Judge Oscar M. Fritz

STATE OF WISCONSIN, MILWAUKEE COUNTY

CIRCUIT COURT. BRANCH No. 2

CITY OF MILWAUKEE, Plaintiff
vs.
THE MILWAUKEE ELECTRIC RY. & LIGHT CO., Defendant
No. 52051

(Issued on February 11, 1920)

The evidence establishes that the Maple Street underground water main, which is a part of the plaintiff's water works system, has been, and is being, damaged, at the intersection of Clinton Street, by electrolysis caused by escaping electric current generated by the defendant. It is important that remedial measures be promptly applied for the elimination of that evil. The accomplishment of that purpose involves a consideration of all metallic underground structures in the zone of the trouble, in order to avoid increasing injury to one, while relieving another. Co-operation (either voluntary or by lawful compulsion) on the part of all interested in such structures is necessary.

The evidence, which has been introduced, does not enable me to reach a conclusion, to a reasonable certainty, that any one of the methods proposed for use in connection with the defendant's single trolley system, will prevent injury to the plaintiff's mains and, at the same time, avoid increased injury to other subterranean metallic structures.

Further evidence, probably necessitating experimental installations, is necessary to warrant a judicial finding as to the proper manner of correction.

On the one hand, plaintiff's counsel proposed, in open court, that the plaintiff is now willing to permit the defendant, at the latter's expense, and in connection with the installation by the defendant of such other devices as it may consider desirable for that purpose, to make such direct metallic connections with the water mains as the defendant may deem proper to conduct the return electric current from those mains so as to avoid electrolytic injury.

On the other hand, the defendant's counsel has proposed that the defendant is willing, without expense to the plaintiff, but under the supervision of the Railroad Commission of Wisconsin, and in co-operation with the other public service corporations, which own such underground structures, to promptly install such devices, as may be approved by the Railroad Commission, calculated to avoid such damage, and, in connection therewith, to provide for the drainage of residual electric current from the plaintiff's water mains by direct metallic connections between those mains and points of low potential on the defendant's return system.

Those propositions, if accompanied by reasonable co-operation between the parties to this section, and between the defendant and the public service corporations, under the supervision of the Railroad Commission, afford the opportunity for a sensible and immediate solution of this engineering problem. That problem has been receiving careful and extended study by the Railroad Commission and its engineers, since 1910. The fact that it has not been finally solved, and that its engineers have differed in the recommendations which they have made from time to time, demonstrates, as do also the judicial decisions in other jurisdictions, the uncertainties and difficulties of the problem.

Since proceedings for that purpose were instituted by the defendant in April, 1918, and study has again been given to that problem under the supervision of that Commission, all of the public service corporations, whose structures were involved, have participated in those proceedings and the investigations which were made in connection therewith, but the City of Milwaukee has not been willing to co-operate, because it denied, and still denies, the jurisdiction of the Railroad Commission insofar as the City and its water works system are concerned.

However, without prejudice to the City, in that respect, and without regard to its attitude in that particular, there is now no good reason why, in view of the foregoing propositions of counsel, the Railroad Commission, with the advantage of its special organization and facilities for the scientific solution of such problems, should not immediately proceed to issue its final order for the mitigation of the electrolysis evil in this City, and why, thereupon, the defendant should not speedily comply therewith and thus prevent further damage to the plaintiff's mains at the intersection of Maple and Clinton Streets.

With reasonable diligence, the defendant can undoubtedly comply with the Commission's order, insofar as conditions at that intersection are concerned, by August 1, 1920, so that, during the month following, the parties can determine whether the evil has been corrected at that intersection.

With those matters in mind, and in the expectation and belief that that course will result either in a practical and satisfactory solution of the trouble, or will enable the parties to offer more convincing proof as to the means that must be adopted to protect the plaintiff's water mains, I shall continue the trial of this cause until September 6, 1920, at 10 o'clock a. m., for such further proceedings, at that time, as may then be proper.

Printed by E. E. Brownell, B. E. E.
Philadelphia, Penna., March, 1920
Consulting Electrical Engineer
City of Milwaukee, Wis.

PART XIX

BEFORE THE RAILROAD COMMISSION OF WISCONSIN

ı the Matter of the Investigation on Request of The Milwaukee Electric Railway and Light Company of the Adequacy of Provision for Preventing Interference with Service Furnished by Other Public Utilities Using Sub-Surface Metallic Structures and the Prescription of Rules and Regulations Necessary to Carry Out the Provisions of Section 1797-1020.

R-2325

The petitioner and the Chicago, North Shore and Milwaukee ailroad and the Milwaukee Northern Railway Company, operate ngle trolley electric systems in the city of Milwaukee. The petioner asserts that the City of Milwaukee, The Milwaukee Gas Light ompany, the Wisconsin Telephone Company, the Western Union elegraph Company, the Milwaukee and Lake Superior Telegraph ompany and possibly other persons, firms or corporations own, aintain and operate certain sub-surface metallic structures in the treets in the City of Milwaukee; and that from time to time the petiioner company has provided means and equipment to mitigate the ijury to these underground structures by electrolysis.

The petitioner desires further in view of expressed complaint ncerning the company's methods that an investigation be made by e Commission, or that one be made by order of the Commission, of e electrolysis conditions maintaining on the sub-surface property the companies mentioned, and of the adequacy of the means lopted by the petitioner for the prevention of the said electrolysis d that rules and regulations be prescribed for the purpose of prenting unreasonable interference between the service of the petitioner d that afforded by other public service corporations or the municility operating underground structures in the city of Milwaukee.

The hearing on the above matter was held at the city hall in the ty of Milwaukee on June 13, 1918, at 11:00 a. m. Representatives the following utilities whose property was affected were present: he Milwaukee Gas Light Company, The City of Milwaukee, The isconsin Telephone Company, the Western Union Telegraph Comny, the Milwaukee Northern Railway Company, Postal Telegraph

Company, The Chicago North Shore and Milwaukee Railway and The Milwaukee Electric Railway and Light Company. The testimony offered consisted largely of a general statement by Mr. G. W. Van Derzee, of The Milwaukee Electric Railway and Light Company, on electrolysis, its cause and the various methods of mitigation together with a statement on what had been done by them to relieve the conditions as they developed.

The hearing resulted in an understanding that the Commission would conduct a survey of the Milwaukee electrolysis conditions, supervised by a representative of the Bureau of Standards, and that the order would be withheld until this work was completed.

HISTORY OF WORK DONE

Up to the year 1900 the only existence of other protection than bonding of rails was a connection between water pipes and the negative bus made in 1893 in the region of the Oneida Street powerhouse.

Between 1900 and 1912 the railway company installed upwards of 350,000 pounds of bare negative cable to supplement the rail return. This copper was connected in parallel with the tracks and was very effective in increasing the conductivity of the return circuit and shunting open rail joints of which there had been a large number. Electrolysis conditions were somewhat improved by the installation of this copper. In addition to the uninsulated return feeders which amounted to approximately 20 miles of cable and 10 miles of Edison tube, insulated feeders have been installed amounting in value to $114,000. Since 1912 the railway company has installed about 420,000 pounds of copper as insulated negative feeders, most of which is in the form of lead-covered cable in ducts. A large part of this copper was installed in 1916 and 1917 and some feeders were not connected until September, 1918. In 1917 the 20th Street Substation was converted for three-wire operation at a cost of about $15,000 and has since been operated in that manner during the morning and evening peaks.

It was also shown at the hearing that the plans of the company contemplated the installation of considerable more one and two million C. M. insulated return feeders.

These statements make it plain that the electric company has had intimate knowledge of the conditions and has made much progress toward the application of the remedies necessary for the prevention of electrolysis.

These various mitigative measures together with some supplementary pipe and cable drainage have greatly improved electrolysis onditions in all areas. Track gradients and overall potentials and otentials of underground structures have been reduced to reasonably ow values and the additional protection required for the pipes and ables in some districts can best be secured by careful co-ordination f drainage systems and other auxiliary means which appear desirable rom time to time.

WORK OF COMMITTEE AND PRESENT CONDITIONS

In accordance with the arrangement made at the hearing, a meeting was held in Milwaukee August 6, 1918, at which a temporary committee was elected consisting of one of the engineering staff of the ommission as its representative and one member from each of the tilities interested. At this meeting, it was arranged to carry on the urvey and that the expense was to be shared by the companies joinng in the survey excepting the City of Milwaukee in such proportion s should be decided by the Railroad Commission.

Mr. E. R. Shepard of the National Bureau of Standards was enaged to superintend the work which was carried to completion about he middle of September, 1918.

The survey conducted by the Commission and carried out under he supervision of the Bureau of Standards was more extensive and omprehensive than had ever been attempted in any past investigaons.

The following observations were made with smoked chart reording voltmeters:

21 overall potential measurements on the tracks.

172 track gradient measurements.

230 potential difference measurements between water hydrants nd tracks.

35 measurements of current flow on insulated negative feeders.

14 measurements of current flow on water pipes.

Potential measurements between cable systems and other strucures were made with indicating voltmeters as follows:

Wisconsin Telephone Company's cables.......	190 locations
The Milwaukee Elec. Ry. & Lt. Co.'s cables....	94 locations
City of Milwaukee cables	70 locations

The Western Union and the Milwaukee & Lake Superior Teleraph Companies conducted their own surveys and submitted them r consideration along with the foregoing data.

Several electrolysis surveys were made in the past years and were of great value in bringing to light areas in which damage was in progress, and in stimulating the electric railway companies to correct bad conditions. Five such reports made in 1906, 1910, 1911 and 1915 were on hand for use in connection with this survey and for comparison of results.

Each of the pipe and cable owning companies submitted a list of failures attributed to electrolysis which had occurred in recent years and these reports were examined and the analysis of the failures seemed to indicate that in a number of instances these failures occurred in localities which it is reasonable to believe have been free from electrolytic action. This leads to the assumption that soil conditions in Milwaukee in certain localities are conducive to excessive pipe corrosion.

A competitive system of drainage exists among the different pipe and cable owning companies whereby each company has its own system of drainage worked out with the view of protecting its system and not having due regard for the dangerous conditions set up by overdrainage in any of the other systems. This was also found to be the cause of some failures.

The following tabulation of rail gradient measurements of this survey compared with a similar survey made in St. Paul and Omaha shows that the conditions in Milwaukee compare very favorably with other large cities.

City	No. of Gradients Measured	Average Gradient Volts per 1000 ft.	Exceeding 0.5 Volt per 1000 ft. No.	Exceeding 0.5 Volt per 1000 ft. %	Exceeding 1.0 Volt per 1000 ft. No.	Exceeding 1.0 Volt per 1000 ft. %
Omaha, 1916	55	0.55	22	40.0	8	14.5
St. Paul, 1917....	81	0.47	28	34.6	7	8.7
Milwaukee, 1918...	172	0.37	42	24.4	6	3.5

The results of the potential measurements between rail and other underground structures as given in the following summaries also indicate generally good conditions.

The potential measurements from water pipe to rail for a total of 230 locations gage only 32 readings over ½ volt positive and 11 readings of over 1 volt positive to the rail.

The potential measurements from Wisconsin Telephone Company cables to rail for 110 locations gave only five readings over .5 volt positive to the rail.

The potential measurements from The Milwaukee Electric Railway and Light Company cables to the track for 66 locations gave no readings over .5 volt positive to the rail.

The potential measurements from the city cables to the track for 51 locations gave only 5 readings over .5 volt positive to the rail.

Potential measurements between the different cable and pipe systems also showed the effect of unequal drainage on adjacent systems and the necessity of co-operation of the different interests in working out a more unified system of drainage for all the underground structures.

The drainage current measurements on the Wisconsin Telephone Company cables show very low values due to the great number of drainage points and to the fact that the drainage points are selected at predetermined low potential points and to the low rail gradients. There are 21 drainage points on this system and the maximum hourly average obtained from any one wire was 51 amperes.

The drainage current measurements on drains to the gas and water mains showed a maximum hourly average of 29.7 amperes from any one of 9 drains located at the different stations. Five other current measurements on mains showed only a maximum hourly average of 10 amperes indicating that the pipes were carrying a very small amount of leakage current; however, this cannot be considered a representative number of pipe locations.

The foregoing data, the reports of other surveys made as noted and other sources of information and observations furnished the basis for the following facts:

Considerable electrolysis of water and gas mains and services occurred in early years principally in the vicinity of the Oneida Street Station which for a time was the only source of railway current in the city and an attempt was made to mitigate this trouble in the vicinity of 27th and Chestnut Streets by bonding the water mains to the railway return circuit at a number of points. Damage to underground structures has continued but in recent years has been much less severe than formerly. The Clinton Street substation district is the one most seriously affected at the present time. Gas service pipes have been damaged in some locations by discharge of current to drained cable systems with which they come in close proximity.

The electrical condition of the tracks is by no means satisfactory. Recent tests of bonds made by the railway company reveal a great number of defective joints, particularly in the southern part of the city. During 1918 about one-half of the city system was gone over and some 4,500 defective bonds repaired. This work was accomplished under a special bonding program initiated by the company and to be continued until this work is caught up.

The results of this survey indicate that the electrolysis conditions in Milwaukee are comparatively good and that the present system of mitigation is principally responsible for this condition.

PLANS FOR FURTHER ELECTROLYSIS MITIGATION

The Commission is of the opinion, however, that further improvements can be made which may be best determined by continuing this survey and while it might be possible to lay down definite limits of track gradient, overall potentials, voltage from pipe to rail, rail bonding, etc., which would be proper under present conditions, it would be impracticable to lay down definite limits which would be proper as well for the present and also for the future with the changing conditions which are sure to come.

We believe that this matter could be much more effectively handled by a permanent committee consisting of representatives of all the interested utilities who should preferably be resident engineers acting with the co-operation of the Railroad Commission, this committee to continue taking the necessary observations and tests to check the conditions periodically, to prescribe such changes, etc., as are needed to maintain proper conditions and to submit a report of these observations to the Commission on suitable standard form to be adopted by the committee. At least one general report on the electrolysis condition should be sent to the Commission in December of each year as well as the copies of the minutes of all meetings of the full committee.

We are of the further opinion that the solution of the problem lies in the plan which has been outlined, viz.: the engineers of all the utilities and electric railways and of the Commission co-operating through a permanent committee.

That co-operation of all whose interests are affected is necessary is emphasized by the statement of Judge Fritz in the case of City of Milwaukee vs. The Milwaukee Electric Railway and Light Company as follows:

> "These propositions, if accompanied by reasonable co-operation between the parties to the action, and between the defendant and other public service corporations under the supervision of the Railroad Commission, afford the opportunity for a sensible and immediate solution of this engineering problem."

In view of the foregoing recommendations and in consideration of the jurisdiction of the Commission in this matter, it is desirable to have the Commission represented on this committee by some one from the engineering staff as an ex-officio member so they may be kept in close touch with the work.

It is therefore recommended that a permanent committee be organized to be known as the Milwaukee Electrolysis Committee with officers consisting of chairman, secretary and treasurer, which committee is to have supervision over the electrolysis mitigation work and the carrying out of such improvements as may be found necessary. The personnel should consist of representatives of each of the utilities with property interests in Milwaukee which are affected by electrolysis conditions, and a representative of the Railroad Commission as ex-officio member. It is suggested that the services of some person be secured who is competent to make the necessary observation, compile records, reports, etc., and whose whole time may be at the committee's disposal. The expenses which the committee may incur in the discharge of its work are to be borne by all the utilities represented on the committee in such proportion as may be mutually agreed upon.

It is further recommended that The Milwaukee Electric Railway and Light Company and all other electric railway companies and utilities within the city of Milwaukee or its suburbs which are in the business of transmitting electric street railway current or whose substructures are subject to electrolysis from this current fulfill such recommendations as may be made to them by the Milwaukee Electrolysis Committee and otherwise co-operate fully with the committee. This committee should be organized at the earliest practicable date and should proceed at once upon its work. The main object of the work should be to prevent the leakage of the negative return street railway current from the rails as far as practicable. This may be accomplished by such additions as are necessary and practicable to the insulated negative return feeder system now in use; by the securing of proper rail joint conductance, and if on further investigation the results warrant its adoption, by the use of three-wire supply systems.

The committee should also investigate the drainage of current from substructures through connections which already exist taking the necessary steps to secure proper measurement and supervision of this drainage and should also make such further drainage taps, with suitable provisions for measurement and inspection, as seem necessary to determine to what extent this plan shall be adopted for the disposal of residual current.

In order to prevent competitive drainage, no connections in addition to those at present in use should be made except upon notice to the committee in writing and these connections should be at all times under the control of and subject to the recommendations of the committee. These temporary or permanent drains should be so installed and controlled as to prevent injury to existing substructures.

The Commission is not disposed to prescribe standards at this time pertaining to overall potentials, track gradients, potential differences, or joint resistance. It is, however, suggested that the following standard for track bonding be established for the present by the committee, namely, that the resistance of 10 per cent of the rail joints shall not exceed that of 10 feet of rail and that this standard is subject to such change as seems warranted by the committee.

The committee should request The Milwaukee Electric Railway and Light Company and other electric railway companies to make regular tests of the joint resistance on its entire system and to submit to the committee the results of these tests. The committee should then decide whether further bond maintenance shall be ordered.

All matters concerning which the committee is unable to come to an agreement should be immediately referred to the Commission for a decision. The committee should submit to the Commission minutes of all regular meetings and a detailed yearly report of the work accomplished and the electrolysis conditions as they exist at that time.

It is ordered that jurisdiction herein be retained for such further order as may be necessary from time to time with respect to matters which cannot be settled to the satisfaction of the parties through the medium of the voluntary committee recommended above, and for such further orders as may become necessary in the event that such a committee cannot be organized or should not accomplish satisfactory results.

Dated at Madison, Wisconsin, this 13th day of April, 1920.

RAILROAD COMMISSION OF WISCONSIN.

JOHN S. ALLEN,
HENRY R. TRUMBOWER,

Commissioners.

JSA:CBH:EB.

PART XX

TESTIMONY OF BURTON McCOLLUM

f National Bureau of Standards, Washington, D. C., in the Case of City of Milwaukee vs. The Milwaukee Electric Railway and Light Company, Before Milwaukee County Circuit Court, February 6, 1920.

(On cross-examination by Clifton Williams, City Attorney)

Cross-examination by Mr. Williams.

Q. You did know, Mr. McCollum, that the City of Milwaukee vestigated the record of your Department and voted on the 28th y of February, 1918, by a vote of 28 to 6, not to have your Bureau ter the Milwaukee field, did you not?

A. I know only that the City of Milwaukee did not join in a quest to the Bureau of Standards to make an investigation in Milaukee. Just what action the City Council took, I can not say.

Q. You know that the record of your Department throughout e United States was investigated by the City Council?

A. It may have been.

Q. Is not this the first time your Bureau ever entered a field ainst the expressed wish of the local municipality?

Mr. Shaw: I object to that as not being a correct assumption. I ow of no such expressed wish. The resolution to which you refer think is merely the resolution by which the City rejected the Comny's offer to arbitrate the question of electrolysis and to abide by d conform to whatever recommendation the Bureau of Standards ight make in the matter.

Mr. Williams: I do not see that counsel has the right to make a eech when I am cross-examining the witness.

Court: The objection is sustained at this time until the assumpn is established.

Mr. Williams: I do not get that, Your Honor.

Court: You assume there was a rejection that has not appeared on the trial yet.

Exception.

Q. By Mr. Williams: You know that as a fact, don't you, Mr. McCollum?

A. I don't know that to be a fact.

Mr. Williams: I offer in evidence page 297 of Exhibit 14, showing a minority report by Alderman Thompson, suggesting that the Bureau of Standards be invited, and that the decision of the Bureau be final and conclusive as to the proper installation of such system and operation and maintenance thereof, and I offer from page 298, where the majority and minority reports were considered and Alderman Thompson moved that the Common Council, from page 299, where the chair put the question: "Shall the foregoing minority report be substituted for that of the Committee?", and it was lost by 6 Ayes and Noes 28.

(Book handed to Mr. Shaw.)

Mr. Shaw: Where is the action which expresses the wish of the City that the Bureau refrain from investigating the matter? That is merely the rejection of the Company's offer of arbitration.

Mr. Williams: Alderman Thompson's minority report in favor of having the Bureau come here.

Court: However that may be, put the next question.

Exception.

Q. Did you know, Mr. McCollum, that the Common Council has handed down this minority report in reference to inviting the Bureau to Milwaukee?

Mr. Shaw: I suggest he be asked whether he knew of a minority report.

A. I know the City Council of Milwaukee had refused to accept the Bureau as arbitrator in the matter, but under the policy of the Bureau, the refusal of any party to accept the Bureau as arbitrator would not interfere in any way with the Bureau's subsequently undertaking an investigation at the request of the Public Utilities Commission.

Mr. Shaw: You mean the Railroad Commission for this State?

A. Yes.

Q. Have you ever entered any other city, has your Bureau ever entered any other American city where you had an expression from the Common Council that the services of the Bureau were not desired?

Mr. Shaw: That is objected to, because it assumed that there was an expression that the services of the Bureau were not desired.

Court: Sustained.

Exception.

Q. Has your Bureau ever entered any other American city where there was a vote by the Common Council against accepting the services of the Bureau?

Mr. Shaw: That does not state it accurately. If the Council is against the acceptance of the defendant's offer to arbitrate...constitutes the Bureau of Standards as the arbitrators. It is not a question of services of the Bureau, but a question of arbitrating and arbitrating in that way.

Court: I think the witness understands the question. You may answer the question.

Exception.

A. So far as I know, there has been no other case in which there has been any such action by a city council.

(Continued)

LAW OFFICES OF
HAGGARTY & BROWN
608 LINCOLN BUILDING
BROAD STREET AND SOUTH PENN SQUARE
PHILADELPHIA

CORNELIUS HAGGARTY, JR.
WILLIAM CHARLES BROWN

March 3, 1920.

Dr. S. W. Stratton, Director,
National Bureau of Standards, Washington, D. C.

Dear Sir: I represent Mr. E. E. Brownell, Consulting Electrical Engineer of this City, who has consulted me regarding the part which certain of your employees took in a litigated matter in Milwaukee and I am quite confident that a reply from you to this letter will put the matter in a different light.

In 1918 the representatives of the National Bureau of Standards made an Electrolytic Survey of the City of Milwaukee, Wisconsin, upon all subsurface metallic structures, as per report of November 26, 1918, and amended on June 7, 1919. Did the Milwaukee Electric Railway & Light Company pay for the time and expenses of your representatives on this survey?

Were your representatives on leave of absence while making the above electrolytic survey and was such work done by them with your full knowledge and consent?

Was it with your consent and approval that Mr. Burton McCollum and Mr. E. R. Shepherd, your representatives, appeared as witnesses before Judge Fritz in the Milwaukee County Circuit Court in the case of "The City of Milwaukee vs. The Milwaukee Electric Railway and Light Company," on February 6, 1920?

Were Mr. McCollum and Mr. Shepherd receiving salaries and expenses from your department while giving testimony as witnesses for The Milwaukee Electric Railway & Light Company?

The courtesy of an early reply will be appreciated.

Truly yours,

WCB/E WILLIAM CHAS. BROWN.

EBR:KRK

DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

ADDRESS REPLY TO
BUREAU OF STANDARDS
I-7/D-I

March 11, 1920.

Mr. William Chas. Brown,
Haggarty & Brown, 605 Lincoln Bldg., Philadelphia, Pa.

Dear Sir: 1. I have your letter of March 3rd asking certain questions in regard to the work done by the Bureau of Standards in conducting an electrolysis survey in the City of Milwaukee in 1918, and giving testimony in a court action bearing on the electrolysis problem in Milwaukee. I take up below the questions in the order in which you present them.

2. As to the matter of defraying the expenses of our representative while engaged on the Milwaukee electrolysis survey, I wish to say that we followed our usual practice in such cases of having our representative, Mr. E. R. Shepherd, take leave without pay from the Bureau of Standards and receive a per diem allowance from the associated utility companies of Milwaukee in lieu of his regular salary. In this case the compensation allowed Mr. Shepherd amounted to $15 per day, out of which he paid his living expenses. It is our custom in making such surveys to arrange for the formation of a joint committee representing the various utilities affected by the survey, and to have a representative of one of the utilities act as treasurer and make disbursements from time to time covering the cost of the survey. After the survey has been completed the total cost is determined and apportionment of the expense made among the various utilities who then compensate the utility which financed the work during the progress of the survey. This practice was followed in Milwaukee where the railway company temporarily financed the survey and was later reimbursed, in part, by the other utilities. The apportionment of expense was made at a joint meeting of the representatives of the various utilities, presided over by Messrs. Hayden and Schmidley of the Wisconsin Railroad Commission, and the following percentages of the total cost of the survey were apportioned to the respective companies:

The Milwaukee Electric Railway & Light Co..	45%
Wisconsin Telephone Company..............	18%

Milwaukee Gas Light Company	22%
Chicago, North Shore & Milwaukee R. R. Co.	6%
Milwaukee Northern Railway Company	6%
Western Union Telegraph Company	3%

You will understand that the survey was made for and at the request of the Wisconsin Railroad Commission which explains the participation of their representatives in the apportionment of the cost of the survey. The $15 per diem allowance was named in advance by the Bureau of Standards and was aimed to be just sufficient to cover his probable living expenses and his usual salary, so that substantially no profit accrued to Mr. Shepherd during the course of this work. The reason why we arrange with the utility companies who benefit by the work to pay the expenses and equivalent salary directly to the Bureau's representative, is to conserve the limited funds which we have available for electrolysis investigation. If the Bureau of Standards were to pay the salary and expenses of its representatives and later be reimbursed through official channels by payments from the utility companies, such payments would not be credited to the Bureau's funds available for this work, but would revert directly to the United States Treasury, and therefore the Bureau would receive no direct benefit from them.

3. Mr. Shepherd undertook this work for the State Railroad Commission with my full knowledge and consent. He was on leave from the Bureau without pay from August 5th to September 23rd, 1918, which covered the period during which the survey was in progress.

4. Mr. B. McCollum and Mr. E. R. Shepherd appeared as witnesses before Judge Fritz in the Milwaukee County Court on February 6, 1920, with the consent and approval of the Bureau of Standards. Our principal reason for sanctioning the appearance of these gentlemen on the witness stand in the case in question was that, having undertaken the investigation for the State Railroad Commission, we did not feel free to shirk any responsibility in the matter and deemed it proper for our representatives to give any testimony bearing on the facts of the case.

5. Mr. McCollum and Mr. Shepherd were permitted to appear as witnesses in the case in a purely non-partisan capacity in order that the full facts regarding the Bureau's relationship to the work might be placed on the records. In view of their appearance as non-partisan witnesses, they were sent to Milwaukee at the expense of

e Bureau of Standards and their salaries while there were paid by e Bureau of Standards, and they received no compensation whatver from any other source.

6. If there is any further information in connection with this atter that you would care to secure, I shall be pleased to have you mmunicate with me.

Respectfully,

S. W. STRATTON, Director.
EBR.

WRITER'S CONCLUSIONS

(June 1, 1920)

1. It is, therefore, very evident from this case, that upon request om a public service corporation, the National Bureau of Standards ill readily accept service and become the paid employees for public tility companies, and at the same time oppose the representative ody of a municipality.

2. It is also very apparent, that to obtain the desired and great- st authority, the National Bureau of Standards will also represent e State, through its public utility commission, against the expressed ublic resolution of the municipality in matters of purely local and roperty-damage cases.

3. It was never intended under our American laws, that the sov- eign rights of a State, through its public utility commission, should er be used in such matters against the common law rights and police owers delegated the municipal authorities. When such is the case tends to seriously divest them of their civic pride, local adminis- ative interest and lawful liberties, and removes the most requisite centive that is so dear to each and every true American.

4. In this case of the City of Milwaukee, Wisconsin, vs. The ilwaukee Electric Railway and Light Company, in the Milwaukee ounty Circuit Court, Judge Oscar M. Fritz (No. 52051), February 6, 1920, it is utterly inconceivable how the representatives of the ational Bureau of Standards could under any circumstance testify non-partisan witnesses in this case, when the City of Milwaukee egislative and legal departments) decidedly opposed their presence this case. They came upon notice and at the request of other pares (paid by the United States Government), not upon any invitation the part of the City of Milwaukee, and were expressly placed upon

the witness stand by The Milwaukee Electric Railway and Light Company, as the testimony in this case will show.

5. Therefore, how in the name of common sense could the testimony of Burton McCollum and E. R. Shepherd be non-partisan, when their presence on the witness stand was against the expressed wish of the legislative and legal bodies of the City of Milwaukee? Impossible!

6. A combination of public service corporation, a sovereign right of a State, backed up by a United States Government Department, to attempt to over-ride a municipality in its common law rights under our national constitutional provisions, would, if successful, result in tearing down our republican form of government.

7. The proper remedy lies in the equity of our courts to adjust such differences, when the public service corporation refuses to arbitrate upon common grounds of fairness and justice.

8. In this instance, the National Bureau of Standards has proven conclusively, in the mind of the writer, that they are impractical (as engineers and operators), inconsistent, decidedly unethical, egotistical and void of the necessary professional dignity becoming a representative of a department of the United States Government.

9. Is there any wonder, therefore, that the City of Milwaukee will not consent to any such imposed authority or accept any of their decisions in this matter? Under these conditions, the Court of Equity has the only binding and legal jurisdiction in the matter of Electrolytic Deterioration upon the Milwaukee Water Works system.

10. If it was the intention of The Milwuakee Electric Railway and Light Company (rather than be defeated otherwise) and other public utility corporations, including the National Bureau of Standards and the Railroad Commission of Wisconsin, to thoroughly complicate this local issue, then they have undoubtedly succeeded far beyond their fondest hopes, but, however, at the sacrifice of the City of Milwaukee. No self-respecting citizen of the City of Milwaukee can consider such apparent high-handed procedure without resentment.

Respectfully submitted,

Consulting Electrical Engineer.

REPORT ON PECIAL ELECTROLYTIC TEST AT MAPLE AND CLINTON STREETS, MILWAUKEE, WISCONSIN

September 4, 1920

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r. Clifton Williams, City Attorney,
City Hall, Milwaukee, Wisconsin.

Dear Sir: In accordance with your instructions certain tests ere made by the writer, assisted by Mr. Robert E. Fritsch. The purse of making the test, at Maple and Clinton Streets on September 4, 20, was to ascertain if the interlocutory court order issued on Febary 11, 1920, by Judge Oscar M. Fritz, as given on pages 339 to 341, clusive, of this report, had been complied with by The Milwaukee lectric Railway and Light Company.

The following conditions were found to exist, namely:

1. On March 29, 1918, electrical current flow tests were made on the 6-inch cast-iron water main on Maple Street at two different ints upon this main—one location just west and the other just east f Clinton Street—known as Stations One and Two.

2. At Station One the maximum electrical current flow passing stward was found to be 4.6 amperes, and Station Two the maximum lectrical current flow passing eastward was found to be 2.8 amperes, us showing a loss of 1.8 amperes between Stations One and Two. hich, if the current flow had been constant, would have taken about 5 pounds of iron per year from this 6-inch cast-iron water main beveen the Stations One and Two.

3. At this time the 6-inch cast-iron water main was electrically ositive to the surrounding earth and rails of The Milwaukee Electric ailway and Light Company on Clinton Street.

4. There were no metallic connections between the 6-inch main n Maple Street and the 8-inch main on Clinton Street at this time.

5. On April 22, 1919, another such test was made and at Station One the maximum electrical current flow passing eastward over this 6-inch water main was found to be 4.2 amperes and at Station Two the maximum electrical current flow was found to be 1.8 amperes eastward, showing a maximum loss between Station One and Station Two of 2.4 amperes, which, if constant, would have taken about 48 pounds of iron per year from this 6-inch cast-iron water main on Maple Street.

6. The 6-inch cast-iron water main at this time was also electrically positive to the surrounding earth and rails.

7. No metallic connections existed between the 6-inch and the 8-inch cast-iron water mains at this time.

8. On January 30, 1920, the maximum electrical current flow eastward over the 6-inch water main at Station One was found to be 3.2 amperes and at Station Two the maximum electrical current flow eastward was found to be 1.6 amperes, showing a maximum loss between Station One and Station Two of 1.6 amperes, which, if constant, would have taken about 32 pounds of iron per year from this 6-inch cast-iron water main on Maple Street. The 6-inch water main was still electrically positive to the surrounding earth and rails with no metallic connection between the 6-inch and 8-inch water mains.

9. On February 3, 4, 5 and 6, 1920, the case was tried in the Milwaukee County Circuit Court, Branch Number 2, State of Wisconsin, before Judge Oscar M. Fritz, and his interlocutory order was issued on February 11, 1920. The case was set for hearing on September 6, 1920.

10. Between February 6, 1920, and September 4, 1920, The Milwaukee Electric Railway and Light Company did certain things in an attempt to carry out this court order, which resulted as follows.

(a) On September 4, 1920, the maximum electrical current flow over this 6-inch cast-iron water main, eastward, was found to be 7.7 amperes at Station One. At Station Two the electrical current flow, now reversed entirely, being westward, reached a maximum over the 6-inch water main of 12.1 amperes, thus, making a total of 19.8 amperes flowing over the 6-inch water main toward the intersection of Maple and Clinton Streets.

(b) This electrical condition showed that there was undoubtedly a metallic connection to this 6-inch water main between Stations One and Two. If not, the electrolytic condition would have taken about 396 pounds of iron per year from this 6-inch water main.

(c) Upon search it was found that the 6-inch cast-iron water main on Maple Street was connected to the 8-inch cast-iron water main on Clinton Street by means of a 1,000,000 c. m. copper cable.

(d) Corporation water cocks were inserted into the 6-inch and 8-inch water mains near the point of intersection and from these two metallic connections two pieces of 1,000,000 c. m. copper cable were inserted and brought together in the manhole of The Milwaukee Electric Railway and Light Company, as shown by personal inspection in this manhole at Maple and Clinton Streets.

(e) In this manhole the two pieces of 1,000,000 c. m. copper cable were joined together, from which was extended a 1,000,000 c. m. copper cable northward through the duct of The Milwaukee Electric Railway and Light Company toward its sub-station located about 200 feet north of the intersection of Maple and Clinton Streets.

(f) The 6-inch water main on Maple Street at Clinton Street was found to be electrically positive to the surrounding earth and to the rails upon Clinton Street immediately above it.

(g) Therefore, the court order of Judge Fritz on February 11, 1920, is not being complied with and the 6-inch cast-iron water main is still undergoing electrolytic depreciation.

11. Further tests will soon be made to determine more accurately what rate of electrolytic deterioration is taking place, under these mitigated conditions, upon the 6-inch cast-iron water main at the intersection of Maple and Clinton Streets.

12. It is extremely difficult to understand why The Milwaukee Electric Railway and Light Company attempted to adopt the use, primarily, of the Pipe Drainage System in order to comply with the Court's order, when upon the witness stand, in this case, their electrical experts (?) condemned it. This is only another example of the inconsistent, ridiculous, contemptible and impractical methods so long practiced by The Milwaukee Electric Railway and Light Company.

13. How can the representatives of the National Bureau of Standards of Washington, District of Columbia, United States of America, reconcile such electrolytic mitigation measures, as a primary means of relieving electrolytic deterioration, when in this case they testified against its use? What is their distinction between the primary and secondary use of the Pipe Drainage System?

14. To install a pipe drainage cable of 1,000,000 c. m. electrical

capacity to drain a 6-inch cast-iron water main of about 20 amperes appears to be rather extraordinary engineering practice. This is only two per cent (2%) of its electrical carrying capacity.

15. If The Milwaukee Electric Railway and Light Company is going to use the Pipe Drainage System, as a means of electrolytic mitigation, primarily, then why not be honest in their dealings and admit its practicability, if properly applied?

16. In my opinion, it would require a great many such pipe drainage connections to the distributing system of the Milwaukee Water Works to render such a valuable system immune from electrolytic deterioration.

17. There has undoubtedly been in use for over 26 years certain pipe drainage metallic connections to the Milwaukee Water Works distributing system. Why did not the National Bureau of Standards investigate the lead-calked pipe joints upon some of these water mains to determine if there existed electrolytic action at these lead-calked joints? They have certainly been in use long enough, yet they investigate such conditions in cities where such pipe drainage connections have only been in use but a few years. There is a reason.

Respectfully submitted,

Consulting Electrical Engineer.

October 4, 1920.

COMPILATION SECTION

Containing

escriptions of Milwaukee's First Street Railway Company —First Electric Street Railway Ordinances—First Electric Light and Ordinance—First Special Report Recommending Electric Street Railway—Estimated Cost of the Electric Street Railway Installation — First Electric Street Railway Car.

so Wisconsin Statutes on Grounded Circuits—Historical and Statistical Records of First Electric Street Railways of America and Europe.

igest of Various Reports on Electrolytic Action upon Subsurface Metallic Structures in the United States, Canada and Europe, Beginning Year of 1890.

Compiled and Cited by
E. E. BROWNELL, B. E. E.,
Consulting Electrical Engineer,
Philadelphia, Penna.

◆

SEPTEMBER, 1920

INDEX TO COMPILATION SECTION

Pages

PART I

History of first street car system in Milwaukee, Wis., 1859.... 3-6

PART II

Milwaukee first electric street railway ordinances in sections. 7-18
Milwaukee's first electric light (1880) and first ordinance..... 19-20

PART III

Milwaukee's original report recommending electric railways.. 21-25

PART IV

Estimated cost of electrifying Milwaukee street railways..... 26
Milwaukee's first electric street railway car in operation...... 27-31
Wisconsin statutes on right of injunction—grounded circuits. 32-33

PART V

Historical and statistical records of electric street railways, in America and Europe, from 1830 to 1892, with tables..... 34-64

PART VI

Milwaukee's City Council resolutions and proceedings on violation of early electric street railway ordinances. In 1890 65-67

PART VII

Earliest electrolytic conditions throughout the United States, Canada and Europe. Citations beginning year of 1890... 68-184

PART I

THE STREET RAILWAY SYSTEMS
OF
MILWAUKEE, WISCONSIN

A BRIEF HISTORY

In July, 1859, the River and Lake Shore Street Railway Company was organized, the following Spring a track was laid on East Water Street from the bridge to Juneau Avenue, and on May 30, 1860, two cars, each drawn by four horses, were run over the line—the first street cars in Milwaukee. In 1865 John Plankinton and others obtained a charter for the Milwaukee City Railway Company and during the next four years constructed several miles of track. Isaac Ellsworth became the owner of all the street railway property in the city in 1869, when he took up the East Side line and relaid the tracks on West Water Street. The lines of the Milwaukee City Railway Company were extended on the South and West Sides and other substantial improvements made, and for the first time the street railways of the city began to pay a small profit on the capital invested. In 1874 two street railway companies were incorporated—the Cream City and the West Side. The former built a line from the corner of East Water and Mason Streets to Farwell Avenue near Brady Street, and subsequently extended it south to Bay View. The West Side Company laid a double track on Grand Avenue from West Water to Eleventh Streets, thence on Eleventh to Wells Street and west on Wells to Twenty-second Street. From this point a single track extended west to the city limits on Thirty-fourth Street. In 1881 Mr. Ellsworth sold his interests to Peter McGeoch and others, who built several new lines, one of them extending to Forest Home cemetery.

The Milwaukee Cable Company was organized in 1887 for the purpose of "constructing a road to run by a low-priced cable, etc." Before the road was built the franchise was so amended as to permit the use of electricity as a motive power and the idea of a cable road was abandoned. The lines of this company ran from Wells Street to Burleigh on Sixth Street; across the Oneida Street bridge, and on Milwaukee Street to Michigan; on Wells Street and north on Eighth to Vliet, thence west on Vliet, with a branch on Eighteenth Street.

The Milwaukee Street Railway Company was organized as a corporation under the laws of Wisconsin in and about the month of December, 1890, being authorized by law to construct, hold and operate street railways in said City and County of Milwaukee, and to own and operate all such railways, franchises, rights and privileges, and to acquire by purchase, conveyance, assignment or transfer all of the railways, properties, franchises and privileges owned by any street railway company in the City and County of Milwaukee; and that between, on and about the 27th day of December, 1890, and the 30th day of January, 1894, the said last named railway company purchased and acquired all of the railways, properties, franchises, ordinances, contracts and privileges theretofore owned by the Milwaukee City Railway Company, Milwaukee City Railroad Company, Cream City Railroad Company, Cream City Railway Company, West Side Street Railway Company, West Side Railroad Company, Milwaukee and Whitefish Bay Railway Company, Milwaukee Cable Railway Company and Milwaukee Electric Street Railway Company, and of each of them as aforesaid, and continued to own and hold the same down to the time of the sale and transfer of said railways, properties, rights, privileges and franchises to The Milwaukee Electric Railway and Light Company and that by various franchises thereafter passed by the Common Council of the City of Milwaukee, and duly approved, there was provision made for the extension by said Milwaukee Street Railway Company of its lines, and the construction of new and different lines, and various other improvements in said city, and that all of said ordinances and rights conveyed by each of said companies was duly accepted by and agreed to by said Milwaukee Street Railway Company.

That prior to the last named transfer, to-wit, on or about October 14, 1889, the Common Council of said City of Milwaukee, by ordinance duly passed and approved, did authorize and empower the aforesaid Milwaukee City Railroad Company, the West Side Railroad Company and the Cream City Railroad Company, their respective successors and assigns, to operate their respective street railway cars by means of power produced by electricity, conducted upon wires suspended over and above their tracks, and along the streets where authorized to maintain street railways, or on which they severally might be thereafter authorized to maintain street railroads, and also severally to erect and maintain necessary plants, machinery and powerhouses for the purpose of generating such electricity, and also severally to erect and maintain in, along and upon the public streets of said city, and under the Milwaukee River or any other river of

ıid city, the necessary poles, cables and fixtures for the purpose ι
›nducting and applying the power to be used as aforesaid; and i
ıd by like ordinance the same power, privilege and authority wa
·anted to the said Milwaukee Cable Railway Company, its succes·
›rs and assigns, passed September 11th, 1889, providing for and em-
›wering said company to operate its lines by electric power.

In the year 1895 the Central Trust Company of New York, a
›rporation and the trustee for the owners and holders of a certain
ortgage or mortgages given by said Milwaukee Street Railway
ompany upon all of its railway property before mentioned, brought
:tion in the Circuit Court of the United States for the Eastern Dis-
ict of Wisconsin for the foreclosure of said mortgage or mortgages;
ıat such proceedings were thereafter had, that on or about Decem-
:r 23, 1895, a decree of foreclosure and sale was duly given and ren-
:red in said court against said Milwaukee Street Railway Company
all of its property aforesaid; and thereafter and on or about Janu-
y 29, 1896, and pursuant to such decree of foreclosure and as pro-
ded therein, all of the right, title and interest of said Milwaukee
:reet Railway Company in and to said railway and property afore-
id, and all of the appliances used in connection therewith, and con-
tuting one entire plant, was sold at public auction to William N.
omwell and others; and thereafter and on or about January 31,
›6, the said Cromwell and others conveyed all of said property and
rights by them acquired to the said The Milwaukee Electric Rail-
and Light Company; and said company succeeded to and now
s all of said railway property and all grants, franchises and prop-
connected therewith and appurtenant thereto.

The Milwaukee Electric Railway and Light Company is a cor-
ion, organized as such on the 29th day of January, 1896, under
›ursuant to Chapter 86 and Sections 1862 and 1863 of Chapter
the Revised Statutes of the State of Wisconsin, and the laws
latory thereof and supplemental thereto; that it was organized
objects and purposes, among other things, of purchasing or
ise acquiring, constructing, equipping, running, maintaining and
ng by electricity or other power street railways for the trans-
›n of passengers in said City and County of Milwaukee in
ıte, and for the purpose of acquiring real and personal prop-
hts, privileges, ordinances and franchises of any street rail-
ıpany, and electric power, light and heat company, foreign
stic, then or thereafter existing, and for extending its rail-
any points in towns adjoining said municipal corporation,

and to build, maintain and use street railways in any village or town, and especially of acquiring and operating all the property, real and personal, rights, privileges, ordinances and franchises of the Milwaukee Street Railway Company, a corporation of the State of Wisconsin, and of the Milwaukee Street Railway Company, a corporation of the State of New Jersey.

PART II

SECTIONS OF VARIOUS ORDINANCES AUTHORIZING THE USE OF ELECTRIC POWER FOR OPERATING STREET CARS IN THE CITY OF MILWAUKEE

XIX.—WHITEFISH BAY RAILWAY COMPANY

AN ORDINANCE

To authorize the construction and operation of a tramway or street railway on certain streets in the city of Milwaukee.

The mayor and common council of the city of Milwaukee do ordain as follows:

> Section 1. There is hereby given and granted to the Milwaukee & Whitefish Bay Railway Company, a corporation created and existing by and under the laws of the state of Wisconsin, its successors or assigns, permission and authority to lay a single or double track for a tramway or street railway in and along the center of the following streets in the city of Milwaukee, to-wit: Commencing at the intersection of Farwell Avenue and North Avenue, thence northeasterly to Bradford Street, thence east on Bradford Street to Glen Avenue, thence north on Glen Avenue to the city limits. And the said railway to keep, maintain and use and to operate thereon railway cars and carriages to be propelled by animal power only upon Farwell Avenue and Bradford Street, and by steam motors or power by animal power or the power of electricity or magnetism, or any one or all of them, as will best subserve the interests and purposes of the company upon that part of its line as hereinabove set forth, lying north of the intersection of Bradford Street and Glen Avenue.

Passed June 14, 1886.

92—AN ORDINANCE

Amending an ordinance passed June 1, 1888, entitled "An ordinance amending an ordinance granting certain rights to the Milwaukee Cable Railway Company," passed December 19, 1887.

The mayor and common council of the city of Milwaukee do ordain as follows:

Section 2. Section 4 of said ordinance is hereby amended by striking out the words "cable road," in the fourteenth and fifteenth lines of said section, and inserting in lieu thereof the words "Railway by the use of electric power," as approved in section 5 thereof.

Section 3. Section 5 of said ordinance is hereby amended so as to read as follows: The cars and carriages to be used on the track or tracks of said railway shall be operated by means of power produced by electricity, conducted upon wire suspended over and above the said tracks along the streets hereinbefore designated by the method known as the "overhead system," and said Milwaukee Cable Railway Company is hereby authorized and empowered to erect and maintain the necessary plants, machinery and powerhouses upon private property owned or controlled by the company, for the purpose of generating said electric power, and said company is also authorized to erect and maintain in or along the streets hereinbefore designated and across or along the Milwaukee river, such poles, wires and cables for the purpose of conducting the power to be used as aforesaid. The poles to carry the wires of said electric railway shall be constructed of iron, in a neat, ornamental manner, and shall always be kept neatly painted by said company and set inside the curb line, and shall not be set at a less distance than one pole in every 125 feet, except at intersections of streets, and the wires shall be conducted not less than 18 feet above the surface of the street. Should said company use in connection with said system any supplemental or feeder wires, such supplemental or feeder wires shall be laid underground. All wires used to conduct electric current shall be constructed with a return parallel metallic circuit, and all work hereby authorized shall be done to the satisfaction of the board of public works.

Passed September 11, 1889.

94—AN ORDINANCE

To authorize the Milwaukee & Whitefish Bay Railway Company to extend its lines of railway.

The mayor and common council of the city of Milwaukee do rdain as follows:

Section 1. There is hereby given and granted to the Milwaukee & Whitefish Bay Railway Company, a corporation created and existing under the laws of the state of Wisconsin, and to its successors and assigns, the right, privilege and authority to lay, construct and maintain a double track for a street railway, with all necessary and convenient tracks and turn-outs, side-tracks, connections, switches and turntables, in, upon and along the streets and bridge in the city of Milwaukee named in the next following sections of this ordinance, and to keep, maintain and use and operate thereon railway cars or carriages propelled only by animal power, or by the power of electricity applied by the underground or storage battery system, upon the conditions heretofore prescribed in the original ordinance granted to said railway company in the right to maintain and operate a street railway in said city of Milwaukee, and subject to the conditions and restrictions hereinafter mentioned, for and during the term of twenty-five years from the date of the passage and publication of this ordinance.

Passed September 23, 1889.

109—AN ORDINANCE

Granting certain rights to the Milwaukee City Railroad Comany, to the Cream City Railroad Company and to the West Side ailroad Company respectively, and amending the respective ordiances granting them certain rights in the city of Milwaukee.

The mayor and common council of the city of Milwaukee do rdain as follows:

Section 1. The Milwaukee City Railroad Company, its successors and assigns, is hereby authorized to operate its street railway cars by means of power produced by electricity conducted upon wires suspended over and above its tracks and along the streets where it is now authorized to maintain a street railroad, or upon which it may be hereafter authorized to maintain a street railroad; and the said Milwaukee City Railroad Company is hereby authorized to erect and maintain the necessary plant, machinery and powerhouse for the purpose of generating such electric power, and is also authorized to erect and maintain in and along the public streets of the city of Milwaukee and under the Milwaukee river, or any other river in said city, the necessary poles, wires, cables and fixtures for the purpose of conducting and applying the power to be used as aforesaid, subject to the restrictions hereinafter contained.

Section 2. The West Side Railroad Company, its successors and assigns, is hereby authorized to operate its street railway cars by means of power produced by electricity conducted upon wires suspended over and above its tracks and along the streets where it is now authorized to maintain a street railroad, or upon which it may be hereafter authorized to maintain a street railroad; and the said West Side Railroad Company, its successors and assigns, is hereby authorized to erect and maintain the necessary plant, machinery and powerhouses for the purpose of generating such electric power, and is also authorized to erect and maintain in and along the public streets of the city of Milwaukee and under the Milwaukee river, or any other river in this city, the necessary poles, wires, cables and fixtures for the purpose of conducting and applying the power to be used as aforesaid, subject to the restrictions hereinafter contained.

Section 3. The Cream City Railroad Company, its successors and assigns, is hereby authorized to operate its street railway cars by means of power produced by electricity conducted upon wire suspended over and above its tracks, and along the streets where it is now authorized to maintain a street railway, or upon which it may be hereafter authorized to maintain a street railroad; and the said Cream City Railroad Company is hereby authorized to erect and maintain the necessary plant, machinery and powerhouses for the purpose of generating such electric power; and is also authorized to erect and maintain in and along the public streets of the city of Milwaukee and under the Milwaukee river, or any other river in said city, the necessary poles, wires, cables and fixtures for the purpose of conducting and applying the power to be used as aforesaid, subject to the restrictions hereinafter contained.

Section 4. All poles erected by any such street railway company to carry the wires of such electric railway shall be constructed of iron in a neat, ornamental manner, and shall always be kept neatly painted by the respective street railway company erecting the same, and all such poles shall be set inside the curb line and shall not be set at a less distance than one pole in every 125 feet, except at the intersection of streets, and the wires to be strung thereon shall be not less than 18 feet above the surface of the street. Should any street railway company aforesaid use, in connection with said system any supplemental or feeder wires, such supplemental or feeder wires shall be laid underground, and all wires used to conduct electric current for the purpose aforesaid shall be constructed with a return parallel metallic circuit; and all work hereby authorized shall be done to the satisfaction of the board of public works of the said city of Milwaukee.

Section 5. The work of construction under the provisions of this ordinance shall be commenced by each street railway company aforesaid in good faith within three months after the passage and publication of this ordinance. And if either or any of the street railway companies aforesaid shall fail to complete the work aforesaid, and to operate by electricity alone the street railway cars upon its entire road by the 31st day of December, A. D. 1890, that then and in such case each street railway company aforesaid so failing to complete its respective road and operate its railway cars thereon by electricity as aforesaid, shall forfeit all rights and privileges granted hereunder, and the board of public works is hereby authorized, and it shall be their duty to remove said poles and wires without further action from the common council.

Passed October 14, 1889.

137—AN ORDINANCE

To authorize the Milwaukee & Whitefish Bay Railway Company extend its tracks and railway, and to operate the same by the use electricity.

The mayor and common council of the city of Milwaukee do rdain as follows:

Section 1. The Milwaukee & Whitefish Bay Railway Company, a corporation duly organized and existing under the laws of Wisconsin, is hereby authorized to extend its railway upon and along the streets and bridges in the said city of Milwaukee hereinafter designated, and for that purpose there is hereby given and granted to the said Milwaukee & Whitefish Bay Railway

Company, and its successors and assigns, the right, privilege and authority to lay and maintain a double track for the said railway, with all necessary and convenient tracks and turn-outs, sidetracks, connections, switches and turntables upon and along the streets and bridges in the city of Milwaukee named in the next following section of this ordinance, and to keep, maintain, use and operate thereon railway cars and carriages propelled by the power of electricity applied by the storage battery, overhead or other approved system, subject to the conditions and restrictions hereinafter named, for and during the term commencing with the passage of this ordinance and ending July 1, A. D. 1924.

Section 3. The said Milwaukee & Whitefish Bay Railway Company is hereby authorized to operate its cars and carriages upon and along its aforesaid track or tracks, by means of power produced by electricity applied by the storage battery system or by means of electricity conducted upon wires suspended over and above the tracks on the streets and bridges aforesaid, and upon such street and approaches as it may hereafter be authorized to lay and maintain a street railway; and the said company is hereby authorized to keep and maintain the necessary plant, machinery and powerhouse for the purpose of generating such electric power, and is also further authorized to erect and maintain on, along and across the streets, alleys and bridges and under the bridges above mentioned in the city of Milwaukee, the necessary poles, wires, cables and fixtures for the purpose of conducting and applying the power to be used as aforesaid subject to the restrictions and conditions hereinafter contained.

Passed August 11, 1890.

AN ORDINANCE

To authorize the Milwaukee & Whitefish Bay Railway Company to extend its tracks and railway, and to operate the same by the use of electricity.

The mayor and common council of the city of Milwaukee do ordain as follows:

Section 1. The Milwaukee & Whitefish Bay Railway Company, a corporation duly organized and existing under the laws of Wisconsin, is hereby authorized to extend its railway upon and along the streets and bridge in the said city of Milwaukee hereinafter designated, and for that purpose there is hereby given and granted to the said Milwaukee & Whitefish Bay Railway Company, and its successors and assigns, the right, privilege and authority to lay and maintain a double track for the said railway, with all necessary and convenient tracks and turn-outs, sidetrack, connections, switches and turntables upon and along the streets and bridge in the city of Milwaukee named in the next following section of this ordinance, and to keep, maintain, use and operate thereon, railway cars and carriages, propelled by the power of electricity applied by the storage battery, overhead or other approved system, subject to the conditions and restrictions hereinafter named, for and during the term commencing with the passage of this ordinance and ending July first (1st), A. D. 1924.

Section 3. The said Milwaukee & Whitefish Bay Railway Company is hereby authorized to operate its cars and carriages upon and along its aforesaid track or tracks, by means of power produced by electricity applied by the storage battery system or by means of electricity conducted upon wires suspended over and above said track or tracks on the streets and bridge aforesaid, and upon such other streets and bridges as it may hereafter be authorized to lay and maintain a street railway; and the said company is hereby authorized to erect, keep and maintain the necessary plant, machinery and powerhouse for the purpose of generating such electric power, and it is further authorized to erect on, along and across the streets, alleys and bridge, and under the Milwaukee river above mentioned in the said city of Milwaukee, the necessary poles, wires, cables and fixtures for the purpose of conducting and applying the power to be used as aforesaid, subject to the conditions and restrictions hereinafter contained.

Passed August 11, 1890.

168—AN ORDINANCE

To amend an ordinance entitled an ordinance granting certain ghts to the Milwaukee City Railroad Company, to the Cream City ailroad Company and to the West Side Railroad Company respecvely, and amending the respective ordinances granting them certain ghts in the city of Milwaukee, passed October 14, 1889.

The mayor and common council of the city of Milwaukee do ordain as follows:

Section 1. Section 5 of said ordinance is hereby amended by striking out the following words, "December, A. D. 1890, where they appear in said section, and inserting in lieu thereof the following words, to-wit: "May, A. D. 1891."

Passed September 8, 1890.

61—AN ORDINANCE

To amend an ordinance entitled an ordinance granting certain rights to Milwaukee City Railroad Company, to the Cream City Railroad Company and to the West Side Railroad Company respectively, and amending the respective ordinances granting them certain rights in the city of Milwaukee, passed October 14, 1889.

The mayor and common council of the city of Milwaukee do ordain as follows:

Section 1. Section 5 of said ordinance is hereby amended so as to read as follows: "Section 5. The work of construction under the provisions of this ordinance shall be commenced by the West Side Railroad Company and the Milwaukee Street Railway Company, the successor of said Cream City Railroad Company, and the Milwaukee City Railroad Company, in good faith, within three months after the passage and publication of this ordinance, and said companies shall complete the equipment of their entire road and operate their cars by electricity by the 31st day of May, 1892."

Passed May 18, 1891.

XXI.—MILWAUKEE & WAUWATOSA RAPID TRANSIT COMPANY

34—AN ORDINANCE

To authorize the Milwaukee & Wauwatosa Rapid Transit Company to construct and operate a street railway.

The mayor and common council of the city of Milwaukee do ordain as follows:

Section 3. The said Milwaukee & Wauwatosa Rapid Transit Company is hereby authorized to operate its cars and carriages upon and along its aforesaid track or tracks by means of power produced by electricity, applied by the storage battery system, or by means of electricity conducted upon wires suspended overhead above these tracks on the streets aforesaid, and upon such other streets and approaches as it may hereafter be authorized to lay and maintain a street railway, and the said company is hereby authorized to keep and maintain the necessary plant, machinery and powerhouse for the purpose of generating such electric power, and is also further authorized to erect and maintain on, along and across the streets above mentioned in the city of Milwaukee, the necessary poles, wires, cables and fixtures for the purpose of conducting and applying the power to be used as aforesaid, subject to the conditions and restrictions hereinafter contained.

Section 4. All poles erected by said company to carry the wires shall be constructed of iron, in a neat, ornamental manner, and of a sufficient strength to support the same, and shall always be kept neatly painted.

All such poles shall be placed with brackets connected to their tops and at right angles to the tracks and of such length that the trolley or feed wires may be fastened from them over the center of the tracks in the center of the streets, and not at the curbs, except at corners where the lines run, where poles may be also placed at the curb line; provided, that upon such streets as may be designated by the chief of the fire department the said company may place its poles at the curb line.

All such poles shall be set at a distance of not less than one pole in every 125 feet, except at the intersection of streets, and all wires to be strung therein shall not be less than eighteen feet above the surface of the street. Should the company use in connection with said overhead system any supplementary or feed wires, such supplementary or feed wires shall be properly and safely insulated, and all wires used to conduct electric currents for the purpose aforesaid shall be constructed with a return paralleled metallic circuit. Said company shall carefully and in a workmanlike manner place its trolley and feed wires upon said poles, and shall break the same from other wires by a proper and suitable wire of sufficient size over said trolley or feed wires. And all of this work shall be done to the satisfaction of the board of public works of the city of Milwaukee.

In case permission be given by the chief of the fire department for the erection of such poles at the curb line, and by reason of excavation under the sidewalks or other cause, said poles cannot be set inside of the said curb line, then the said board of public works may, upon the application of said corporation, permit the same to place the said poles outside of and immediately adjacent to the said curb.

Passed June 1, 1891.

XXIX.—CHICAGO & MILWAUKEE ELECTRIC RAILWAY COMPANY

158—AN ORDINANCE

Authorizing the Chicago & Milwaukee Electric Railway Company to construct, maintain and operate a system of railway upon certain streets, in the City of Milwaukee.

The Mayor and Common Council of the City of Milwaukee do ordain as follows:

Section 1. That right, permission and authority are hereby given and granted to the Chicago & Milwaukee Electric Railway Company, a corporation duly organized and existing under the laws of the state of Wisconsin, hereinafter called the "grantee" and to its successors and assigns, to construct, maintain and operate a double track electric railway, except as hereinafter stated, with all necessary sidetracks, switches, Ys, curves, turnouts and connections, poles, wires and feeders, and other appliances, or conveniences, necessary or usually employed in the operation of an electric railway, over and upon the following streets and avenues, in the city of Milwaukee, and over and across all intersecting streets and alleys, and all bridges and viaducts, between the terminals hereinafter specified, viz.: (Then follows route).

Section 4. The electric current for the operation of the railroad shall be furnished from an overhead trolley suspended upon iron poles. Such poles shall be located on the property line side of the curb of said streets, subject, however, to the approval of the board of public works of said city. And said poles shall not be more than one hundred feet apart. The trolley shall be suspended not less than eighteen feet above the grade of the street.

Section 6. In consideration of the rights and privileges hereby granted to said grantee, the said grantee shall at all times furnish to said city electric power sufficient to swing and operate all draw bridges, now or hereafter maintained by said city, and crossed by said grantee, and said grantee shall furnish and provide all necessary connections, conductors, circuits and everything whatsoever required to connect said bridges with power plant or plants maintained by said grantee, so that the electric power can be thereby properly and safely transmitted and applied.

Passed February 26, 1906.

NOTE—The above franchise would have expired December 31, 1934, but now under the direct jurisdiction of the Wisconsin Railroad Commission.

XXI.—MILWAUKEE-NORTHERN RAILWAY COMPANY

174—AN ORDINANCE

Authorizing the Milwaukee-Northern Railway Company to conruct, maintain and operate a system of railway upon certain streets the City of Milwaukee.

The Mayor and Common Council of the City of Milwaukee do dain as follows:

Section 1. There is hereby given and granted to the Milwaukee-Northern Railway Company, its successors and assigns, the right, permission and authority to lay, construct, maintain and operate a single or double track for street railways, for the carrying of passengers, with all necessary turn-outs, sidetracks, connections, cross-overs, and switches, and to erect and maintain necessary and convenient poles on the streets, highways, bridges and viaducts hereinafter mentioned, of the city of Milwaukee, and in the manner and upon the conditions herein set forth.

Section 2. (Third paragraph).

Said railway company shall operate over the street railway local and interurban cars and carriages by means of power produced by electricity, conducted upon wires suspended over and above its tracks, or such other power as may be agreed upon between said city and the said railway company, its successors and assigns; provided, however, said railway company shall at all times operate a reasonably convenient local street railway service as measured by other service of similar nature in said city of Milwaukee.

Section 3. All rights reserved or secured to said city by and under all ordinances now in force, or the laws of the state of Wisconsin relating to regulating the speed and headway of cars, the time that cars shall be operated each day, the laying of tracks, stringing of wires, and the use and operation of all cars and tracks, and everything connected with the exercise of the rights hereby granted to said railway company, are hereby reserved to said city, the same as though this ordinance had not been passed.

Section 5. All of the rights, privileges and franchises conferred by this ordinances shall be for and during the term commencing at the passage and publication of this ordinance, and acceptance thereof, and ending December 31, 1934.

Section 7. In consideration of the rights and privileges hereby granted to said railway company, the said railway company shall at all times furnish free of all cost to said city electric power sufficient to swing and operate all draw bridges now or hereinafter maintained by said city and crossed by said railway company, and said railway company shall furnish and provide all necessary connections, conductors, circuits and everything whatsoever required to connect said bridges with the power plant or plants maintained by said railway company, so that the electric power can be thereby properly and safely transmitted and applied.

Passed March 22, 1906.

MILWAUKEE'S FIRST ELECTRIC LIGHT

The first electric light was used in the City of Milwaukee, Wis., n April 5, 1880. The Milwaukee Sentinel of April 6, 1880, contains he following news item:

"Last evening large numbers of people congregated at the New- all House, directed thither by the wondrous little electric spark, hich appearing no larger than a small-sized marble, gives forth rilliance equal to 1,000 candles.

"There were two lighted, one of them was directly above the nain entrance, and although surrounded by a ground glass globe, ighted the street so as to admit of reading finely printed matter with- ut difficulty. The machine used is a Weston dynamo machine kept n motion by the Newhall steam engine and consumes about two orsepower.

"It was pronounced by Prof. Haskins and E. C. Drake of Newark, ew Jersey, to be a success, except in the fact there was no governor n the engine to regulate the power so as to make the light absolutely teady."

MILWAUKEE'S FIRST ELECTRIC LIGHT ORDINANCE

XVIII—BADGER ILLUMINATING COMPANY

AN ORDINANCE

Granting certain rights to the Badger Illuminating Company.

Section 1. Badger Illuminating Company, a corporation organized under and by virtue of the laws of Wisconsin, having its principal office in Milwaukee, its successors and assigns, is hereby authorized to construct and maintain in the streets, alleys, tunnels and public grounds of the City of Milwaukee, a line or lines of wires or other electric conductors to be used for the transmission of electricity, generated and supplied by the Thompson-Houston improved system of arc and incandescent lighting, or such other system of electric light as the Common Council may decide to adopt for the purpose of furnishing light, heat, power and signals.

(Last paragraph of Section 2)

Along the other streets and alleys of the city the said company may stretch its conductors upon poles; said conductors to be properly insulated; said poles to be of first quality, not to be more than one hundred and fifty feet apart, and shall in no case support the wires less than thirty-five feet in height, and shall be arranged so as to support the conductors over the center of the street; and the circuits to be none other than metallic circuits. The City of Milwaukee shall at all times have the right and privilege to use the poles of the said company for the purpose of stretching and maintaining thereon a line or lines of wires for the use of the fire department, the police department or any other department of the city government, without any compensation therefor.

Section 9. The Badger Illuminating Company shall not at any time pool or assign their interests, nor consolidate with any other electric light company, which may hereafter obtain a franchise to do business in this city; and if said Badger Illuminating Company shall pool their interests or consolidate with any other illuminating company without the consent of the Common Council, then this ordinance shall be null and void.

Section 10. It is hereby expressly enacted that the Milwaukee Gas Light Company is prohibited from acquiring any interest whatever in the said Badger Illuminating Company, and if the said Badger Illuminating Company shall allow said Milwaukee Gas Light Company to acquire any interest whatever in said Badger Illuminating Company, then this ordinance shall be null and void.

Section 12. This Ordinance shall take effect and be in force from and after its passage and publication.

Passed November 21, 1885.

PART III

REPORT SPECIAL COMMITTEE TO INVESTIGATE THE ADOPTION OF ELECTRICITY FOR OPERATION OF STREET CARS IN MILWAUKEE, WISCONSIN

COMMON COUNCIL PROCEEDINGS

(1889-1890, Page 249)

Ald. Steinman in the Chair.

President Hinsey, in behalf of the Milwaukee Cable Railway Company, made the following proposition, viz.:

That his Honor, the Mayor, the City Engineer, Chief of the Fire Department, seven members of the Common Council and such other city officials as the Mayor may invite, visit Boston, New York and other cities where electric railways are in operation. The entire expense to be borne by the Milwaukee Cable Railway Company.

Ald. Roberts presented the following:

Resolved, That the proposition submitted by J. A. Hinsey, in behalf of the Milwaukee Cable Railway Company be accepted and the following aldermen appointed a committee to visit Boston and other places for the purpose of thoroughly investigating the question of electricity as a motive power for propelling street cars, and other purposes:

Ald. Ramsey, Obenberger, Bechtner, Steinman, Grant, McCoy and Altpeter.

Upon motion the rules were suspended and the resolution adopted by the following vote, viz.:

Ayes—28.

Noes—7.

Ald. Bechtner moved that when the Council adjourns it adjourn to meet on Monday, August 19, 1889, at 4 o'clock p. m., to hold a regular meeting.

The motion prevailed.

(Page 271)

By Ald. Jordens:

Whereas, A committee was appointed by Mr. J. A. Hinsey to investigate the different systems of electric street railways in eastern cities, and

Whereas, As this committee receives their compensation from the interested company and therefore apt to report in favor of this company, and

Whereas, The citizens of our whole city, from South Side and West Side, as well as from the East Side and North Side, are interested in this matter, and should be recognized, therefore be it

Resolved, That the Mayor is hereby instructed to appoint a committee, consisting of the Mayor, two aldermen from each side of the Milwaukee River, and one citizen from each side of this river for the purpose of investigating the different systems of electric street railways in Boston, New York, Philadelphia, Washington, Cleveland and such other cities where electric systems are in use, and report to this Council their findings.

The committee so appointed shall receive no compensation, but the city shall pay all expenses for the round trip.

Referred to the Committee on Finance.

(Page 298)

By Ald. Bechtner:

Resolved, That the City Engineer and the Chief of the Fire Department be and are hereby requested to communicate to this Council, at its next meeting, their observations and conclusions based thereon, obtained in part during their recent visit to eastern cities, as to the practicability of using electric power as a motive power for street railways.

Upon motion the rules were suspended and the resolution adopted.

(Page 331)

The chair presented the following:

City Engineer's Office, Milwaukee, Sept. 9, 1889.

To the Honorable the Common Council:

Gentlemen: In obedience to a resolution passed by your honorable body on August 19, 1889, requesting me to communicate to you my observations and conclusions made during a recent trip to eastern cities as to the practicability of using electric power for street railways, I would submit the following brief statement.

At Boston, the West End Street Railway Company, controlling over 240 miles of street railway, has spent considerable time and money in thoroughly investigating the different systems of propelling street cars aside from horse power, and after careful study came to the conclusion that electricity would give them the best results, whereupon, they tried both the conduit and overhead systems. From all I could learn from the street railway people, from citizens or officials, or engineers at New York, the underground or conduit system was generally considered a failure, causing almost endless annoyance and stoppages of the cars until all, both public and the company, demanded a change; during the same time the overhead system gave good results and excellent service, and has been extended over the route originally operated with the conduit system, giving there also the best of satisfaction. The company has now been authorized to extend the overhead system over its lines in and through the densest business portion of the city and where the streets are the narrowest. A number of routes are now in operation and furnish rapid, safe and satisfactory transit.

At Lynn, Mass., the route operated by the electric (overhead) system is very crooked, has many very short curves and steep grades, approaching 12½ feet per hundred, and it was there demonstrated that the electric motor can very easily overcome both successfully. It was even demonstrated that with a load the car can be stopped midway on that heavy grade and caused to run back up hill.

At Cleveland it was demonstrated on the Central Viaduct line that with a trail car attached, a speed of about 20 miles per hour can be obtained and yet be safely handled and the cars be stopped and started quickly. Trail cars were used on both this and the Euclid Avenue line, and three cars, well loaded down with passengers, were handled with ease, safety and speed. Here, as well as at Cambridge it was demonstrated that the overhead electric line has an advantage over cable lines in crossing draw-bridges, connections being so made, that the opening or closing of bridges does not interfere with the running of the cars on any part of the system nor over the bridge when closed.

At New York City, on the Fourth Avenue line, the cars were propelled by the Julien Electric Storage batteries, the motors being the same as those used on most of the overhead system cars, the difference in the two systems being merely that in one there is a central powerhouse where the electric current is developed and conducted by overhead wire to the motors on the cars, while in the other the cars carry under the passenger seats the batteries previously charged with electricity and from which the current is supplied to the motors as needed, each car carrying independently within itself the power and the motor. On the above line ten such cars were in operation and were running on regular schedule time so that it was impossible to ascertain then by trial, what speed could be developed, but the cars run smooth and were as easily managed as those of the overhead system, making the run from the post office to Eighty-sixth Street, the terminus of the run of the electric cars (being about six miles), in one hour. Each car made a run of twelve miles, using up about twelve electric horse power, at the end of which run the batteries are changed at a loss of about three to four minutes. It is claimed by the Julien people that they can maintain a speed of twelve to fifteen miles per hour and haul a trail-car as well, but that when the grade exceeds 6 per cent, auxiliary power should be used to overcome the same, which they recommend should be horse power. The Fourth Avenue line has ordered twenty more cars, some of which were about ready for delivery.

In all these systems the cars are lit up by electricity supplied from the same source that supplies the motors and independently from these.

From what I could learn the snow at the places had offered no obstacle to the running of the cars last winter.

In addition to the above I wish to say that the overhead system, if put in, can be laid so as to furnish the power to turn such bridges by electricity where such lines cross the river, which would cheapen and increase the speed of the opening and closing of such bridges.

I believe, from the many lines of electric street cars I have seen in many of the cities and towns on the way to and from the east, and from inquiries being received and investigations made by parties from all larger cities, that electricity will become the acknowledged proper power for propelling street cars in the next five or six years, as it has become the recognized light.

Respectfully submitted,

G. H. BENZENBERG,
City Engineer.

I concur in the above statement.

JAMES FOLEY,

Chief, Fire Department.

Upon motion of Ald. Obenberger action on above communication was deferred until the next regular meeting.

Report ordered on file Sept. 23, 1889 (page 348).

(Page 358)

Ald. Steinman, from the Committee on Finance, reported back a resolution to appoint a committee to investigate different systems of electric street railways and recommend that its further consideration be indefinitely postponed.

The report was adopted.

PART IV

ESTIMATED COST OF ELECTRIFYING TWO MILWAUKEE STREET RAILWAYS

(Engineering News, February 23, 1889, Page 177)

Milwaukee, Wis.—It is stated that the Milwaukee City Railway Company intends to run its cars by electricity. It is also expected that a street car lighted and propelled by electricity will shortly be exhibited. This car is being fitted up in Detroit with storage batteries manufactured under the Woodward patents, the rights of which, for Wisconsin and Upper Michigan, have been secured by the Wisconsin Storage Battery Co., a Milwaukee corporation with a capital stock of $50,000. President H. H. Stafford; Vice President, A. G. Weissert; Treasurer, DeWitt Davis; Secretary, H. T. West.

(Engineering News, November 1, 1890, Page 406)

Milwaukee, Wis.—Newspaper reports state that electricity will probably be used on the Milwaukee City and the Cream City street railways. The Sprague system will be adopted, and the cost of the change is estimated at $2,000,000, there being over 100 miles of track to be relaid with heavier rails.

THE PROPOSED FIRST CONDUIT SYSTEM

(Engineering News and American Contract Journal, 1886, Page 29)

Milwaukee, Dec. 23—A few weeks ago the city granted a franchise to the Dorsett Underground Service Company to establish an extensive system of conduits, and the initiative steps were taken for putting in a $500,000 plant. It now develops that an agent who had been given power of attorney to dispose of the company's stock had made a sale to an opposition company of whose conduits little is known. The Mayor has declined to approve the bond of the new stockholders and legal action will be taken by the Dorsett people. It is likely that at the next meeting of the city authorities the company's franchise will be revoked, should no other way be presented for blocking the conspiracy against the original company.—N. Y. Tribune.

˅IILWAUKEE'S FIRST ELECTRIC STREET RAILWAY CAR

(Copy)

(From the Milwaukee Sentinel, April 4, 1890)

WENT AS ON WINGS

rst Electric Car Makes Its Debut—Modestly Takes the Suburbs for the First Run—Col. Becker Gets the Start of Col. Hinsey—Trip Made to Thirty-fourth Street from the Powerhouse—The Display of Sparks and Fire Scares People and Horses.

Col. Hinsey may as well take a back seat. In spite of all his 'omises and the encouraging words from The Sentinel, Col. Becker ıs succeeded in starting out the first electric car in Milwaukee. It ade two successful trips on Wells Street last night and it is ex- :cted that cars will be running regularly tomorrow.

The West Side Street Railroad Company waited for the shelter ſ darkness before making its debut as an electric road. But the ap- earance of the first car had been so well heralded that it was impos- ble, when the appointed hour arrived, to make the start without ıe assistance of a crowd of spectators, composed of men, women, ɔys and girls, who surrounded the powerhouse on Wells Street. ar No. 61, which was selected for the test, was taken out of the shed : 4 p. m., and the much-talked-of and mysterious trolley party ad- ısted. Early in the afternoon, however, the great Corliss engine was ɪt in motion and the generators sent the currents of electricity along ıe line. Everything was all right except at a point on Wisconsin treet between Broadway and Milwaukee Street, where a break was iscovered. This caused a delay, and it was after 7 o'clock when the 'olley was thrown against the wire over the car for the first time. here was a big crowd on hand to see the fun.

Sparks Begin to Fly

The application of the trolley to the wire drew from the latter stream of blueish-red sparks and from the spectators a chorus of "oh's." Some of the people who had gathered to see the start were frightened and as cautious as an Indian who had never seen a locomotive. They looked for dry places for their feet, but couldn't find them. The man who knew all about electricity and how it would creep into the sidewalks, the cobble stones, the trees and everything else was there, and he was generous in his advice to those who insisted upon leaning up against the poles and standing upon the car tracks. When the sparks began to fly this disciple of Edison was the first to disappear around the block. A moment later, by the slightest application of the trolleys, the operator moved the car from the side to the main track, and by a firmer hold upon the wire he soon set the ball to rolling, and away went the car!

It was a circus for the small boy and a spectacle of no little interest even to those who have lived to see the telegraph and the telephone put into practical use. A few employes of the line, a policeman, a reporter and the ever-present and not-to-be-crowded-out street urchin were upon the car as it shot out upon the track in the direction of Thirty-fifth Street with a whiz-z-z-z-z that made even the tame and docile bronchos of the old system prick up their ears and shy to one side.

At a Rapid Rate

The car started off at a rapid rate but was easily regulated by the manipulation of the trolley rope in the hands of the operator. The application of the electricity also illuminates the incandescent lamps of the car and fills out the big headlights at either end with brilliant rays that are thrown along the street for several blocks; but the stopping of the car, last night, at least, left the policemen, the reporter and the small boy alone in gruesome darkness.

The car made two trips along the Wells Street line to Thirty-fifth Street and back to the powerhouse without accident, yet it was apparent that the horses of the city had a monster to become used to. for they all pranced and snorted at its approach in a way not at all reassuring to nervous people. The franchise required that all the cars to be in operation by April 1, but it is doubtful if the line will be in good running order before Saturday as there are many details to be remedied, which can not be done until experiments develop the defects.

(Copy)

(From the Milwaukee Sentinel, April 6, 1890)

RUNS WITH A BUZZ

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lectric Cars Are Better Than a Circus—Blue Light Meteors With Trains of Fiery Sparks—They Work Smoothly and Cause Little Disturbance—Will Probably Be Successful from the Start—Rapid Transit Assured.

The polished oaths of the countless Jehus of Milwaukee filled the r, and loud and far above the objurgations of the drivers rose the zzling buzz and crackling rumble of the Becker electric cars. Horses ho had never known what astonishment meant, pricked up their rs and stood still in dumb amazement, giddier steeds, whose sires' oroughbred blood still coursed among their veins, betrayed symp- ms of electrified uneasiness. The better trained amongst them just rned toward the sidewalks and pranced, those who lacked culture d the faculty of "nihil amirari" got upon their hind legs and bolted d behaved as unbroken bronchos do on the advent of a prairie fire.

Gaping crowds lined the sidewalks, on every corner a curious ultitude stood in waiting anxiety, and in the middle of every throng as posted a Milwaukee policeman who awaited with hands out- read and bulging eyes and protuberant stomach the advent of the e-spitting vehicle.

In the early afternoon they assembled and waited for the prophe- ed arrival of the car. If the Becker line cars were duly authenti- ted prophets and the crowds expectant believers no greater interest uld have been excited in their advent. As it was their distant ap- arance was hailed with loud paens of delight, and only the nearby hu, with his horse and maybe his living cargo of mortals to look ter, heaved curses on the sizzling rumbles of the horseless car. For e uneducated equines of the period loved not the sizzler and ca- rted and pirouetted at its approach and made bee-lines for dwelling uses and lampposts; be it said, however, to the credit of all Mil- aukee horses, none of them got up and bolted outright. But away f in the northwestern end of the city where new things are scarce d unusual attractions rare, the populace joined with the horses in a ild demonstration of awe, and historical epochs will be dated from e advent of the fire-spitting street car.

Lightning on Roller Skates

It was long after 3 o'clock when the first spitting, glittering harbinger of the triumph of electricity came humming down Grand Avenue like a streak of lightning on roller skates. It rumbled and thundered along on its mad career, it spluttered and fizzled, and the sparks that scampered from its wheels and the copper wires overhead were suggestive of cerulean hell.

"Ach Himmel!", ejaculated the blonde moustached but intelligent police official on upper Grand Avenue.

"Be the laws!", said the ever affable Officer O'Brien on the corner of the avenue and West Water Street.

"Be the laws," again quoth he as he saw the yellow monster of the flaming vomit come switching down toward the bridge with its great black street trolley expectorating blue sparks overhead like the right arm of Lucifer, "Be the laws," quoth he, "if they don't let up on that pace afore they reach the bridge its arristin' the whole outfit I'll be after doin'."

Club in hand he waited as the thundering monster rattled down, but at the Plankinton block the pace lessened and the vehicle slowed down into restfulness ere it reached the corner of West Water Street. There it was pulled over the switch. Under the watchful eye of Secretary Durnin and the Sprague Company's expert, the assistants gave a chuck at the prehensile trolley with the guy rope and switched it over to the upper line; the car was switched, the return trip commenced, the yellow horseless monster trundled back again up the avenue amid a crowd of yelling urchins and the suppressed murmurs of an amazed Milwaukee crowd.

A Sentinel reporter stood on the front platform with the expert and the officials to see that everything was O. K., and though his experience in the matter was small there can be no doubt but that his presence effected a vast amount of moral good with all parties concerned. For instance, when a particularly risky switch or curve was reached, the reporter would divert the guiding expert's attention from the harrowing uncertainties of the occasion by aptly inserted queries anent the inner mechanism of electrical cars, and when a horse shied on the off sidewalk the reporter would avert all distress from the official's mind by calling his attention to the pleasant landscape that adorned the other side of the way.

Didn't Carry Passengers

An occasional incident would break the dull monotony of admiration the trip excited, as for instance, up in the northwestern end of the city, where, at every block or so, an interested and inquisitive citizen would drop off the tailboard of some horse-car and hail the electric vehicle in stentorian syllables. God bless 'em, they might as well have hailed the planet Saturn for all the satisfaction they got; for on either end of the car iron lattice-work gates forbade the ingress of the stranger or the egress of the passenger, and while the guard ahead shouted out, "This car doesn't carry any passengers, sir," the expectant citizen shook his fists and committed the grievous sin of blasphemy, the surrounding crowd shouted and cooed hilariously, and the car with the blue fire vomit proceeded exultantly on its way.

From West Water Street away down to the end of the Twelfth Street track the electric cars ran and the electrified crowds assembled. Up in the German quarter it seemed as though a circus were abroad, for, gentle and simple, old and young, every man, woman and child in the district seemed to be waiting for the car on the corners. How they all learned about its coming, goodness only knows, but on its first trip they were all standing there in poses of the mutest amazement. On its return trip they were there still and not one expression of astonishment had altered itself, and on the final trip were still on the spot and not even one soupeon of weariness had supplanted the wrapt gaze of astonishment on every countenance.

Looks Like a Success

On the two trips there was no instance of a horse shying badly or running away with fright; but, on the other hand, though many did grow restive, comparatively few of the equines seemed to pay the least attention to the new electrical monster. A trip up Wells Street from the Twelfth Street stables after the successful experiment on Grand Avenue was likewise unattended by accident; and on the whole it looks as though there is a probability of our having a regular electrical street car service in Milwaukee this week. At present of course the Grand Avenue bridge transfer switches are not reliable enough to be put in use, and all the cars have not been thoroughly tested. They will be ere Friday next, however, and if they all prove as satisfactory as those already tried, the Becker Company will complete the purchase with the Sprague concern and Milwaukee will blossom forth in a glittering, sizzling, rumbling service of electrical street railways.

WISCONSIN STATUTES

1917

Embracing all General Laws in Force at the Close of the General Session of 1917, Consolidated and in Part Revised Pursuant to Sections 43.07, 43.08, 35.18 and 35.19 of These Statutes.

Chap. 86 s. 1780b) (Corporations

Electrical companies. Section 1780b. Any corporation organized under general or special law for the purpose of furnishing heat, light, power or signals by electricity may, with the consent of and in the manner agreed upon with the authorities of any city or village, use any street, alley, lane, park or public ground for constructing, maintaining and operating its lines with all necessary wires, conduits and appurtenances for the purpose of supplying light, heat, power or signals to such city or village or to any building, manufactory, industry or public or private house therein; provided, no permanent injury shall be done to such street, alley, lane, park or public ground. The provisions of this section shall apply to any corporation heretofore organized and now operating an electric light plant by the consent of the authorities of any city or village. Such corporation shall also have the powers conferred by section 1775, and it shall be the duty of such corporation and of each and every person engaged in the transmission of electrical energy to provide, by suitable insulation, return wires or other means, against injury to persons or property by leakage, escape or induction of any electric current. Neglect of these provisions shall entitle any person thereby endangered or injured to a preliminary injunction preventing further use of such current until such insulation be made. (1879 c. 211; 1882 c. 208; 1889 c. 375; Ann. Stats. 1889 s. 1780, 1780a, 1791b; 1893 c. 192; Stats. 1898 s. 1780b.)

AN ACT
RELATING TO ELECTRIC COMPANIES

Chapter 375

The people of the State of Wisconsin, represented in Senate and Assembly, do enact as follows:

Section 1. It shall be the duty of each and every electric light and power company, and of each and every person engaged in the transmission of electrical energy within this state, to provide by suitable insulation, return wires or other means against injury to persons or property by leakage, escape or induction of any and every current of electricity.

Section 2. Neglect of any of the above provisions shall entitle the person or corporation injured thereby to a preliminary injunction, preventing further use of such current until said Section 1 has been complied with.

Section 3. This act shall take effect and be in force from and after its passage and publication.

Approved April 15, 1889.

Published April 15, 1889.

PART V.

BRIEF HISTORY OF FIRST ELECTRIC RAILWAYS

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The years 1830 to 1860 mark the first period of experiment in the application of electrical energy for transportation. The work of experimenters was limited to the application of permanent magnets and reciprocating motion, and by the lack of serviceability and capacity from chemical batteries.

About 1835, Thomas Davenport, of Brandon, Vermont, made over one hundred models of electric railway motor cars, which he operated by batteries. One patent specified, "The production of rotary motion by repeated changes of magnet poles," and the use of a commutator. Third-rail conductors and track-return circuits were used.—Electrical World, Oct. 6, 1910.

In 1842, Davidson built a seven-ton, two-axle car for the Edinburgh-Glasgow Railway. Each axle carried a wooden cylinder on which were fastened three bars of iron, parallel to the axle. Four electromagnets were arranged in pairs on each side of each cylinder. Current was produced by an iron-zinc sulphuric acid battery. The electromagnets attracted the bars on the cylinder, then alternately the current was cut off and on, and rotation was produced. A speed of four miles per hour was obtained.—Aspinwall, to Institution of Mechanical Engineers, 1910.

In 1847 Lilley and Cotton, of Pittsburgh, and also Moses G. Farmer of Dover, N. H., operated small cars in which, with electricity from a battery, alternate attraction and repulsion of magnets produced motion.

In 1851, Thomas Hall, of Boston, exhibited an electric motor car at the Mechanics' Fair. An electro-magnetic armature revolved between the poles of a permanent magnet.

In 1851, C. G. Page, of Washington, D. C., employed a 100-cell nitric-acid battery. His car received motion from two solenoids, or hollow magnets, which alternately attracted cores on a plunger. This reciprocating motion was transmitted to the wheels by means of a crank. A speed of 19 miles per hour was attained, yet very few improvements were made, and the car was dubbed the "electro-magnet humbug."

Between 1860 and 1866, dynamos or electric generators were being developed; yet it was some time before it was discovered that an electric generator could drive a similar machine, now called a motor.

In 1867, Moses G. Farmer operated a car with a motor and dynamo.

In 1879, Siemens and Halske, at the Berlin Industrial Exhibition, propelled a miniature locomotive and three cars, with electric power from a dynamo. The track rails, 1000 feet long, formed a 160-volt circuit. Spur and bevel gears were used to transmit the power from a 3 H. P. motor. This demonstration was repeated at Brussels and Dusseldorf, also at Frankfort, in 1881. See photograph in Street Railway Journal, Oct. 8, 1904, p. 536.

In 1880, Thomas A. Edison at Menlo Park, New Jersey, ran a small locomotive, using power from a dynamo. See section on electric locomotives in this chapter.

In 1881, Stephen D. Field ran a large motor car at Stockbridge, Massachusetts, using a dynamo, a positive wire enclosed in a conduit, and a track-rail return.

In 1881, Siemens operated cars at the Paris Exposition with current from an overhead slotted tube in which a contact shoe slid, and power was transmitted by the motor to the axle through a chain; and, in 1885, at the Vienna Exposition, a 150-volt Siemens dynamo supplied current through two insulated rails to a motor in a car.

In 1883, Van Depoele built experimental and exhibition lines at Chicago, and used an overhead trolley wire, an over-running trolley wheel, held in position by ballast, the trolley wheel being connected to the car by means of a flexible cable.

In 1884, Van Depoele ran an electric railway train at the Toronto Exposition, using a 1000-volt contact line in an underground conduit, 3,000 feet long; and again in 1885, on a one-mile road. Van Depoele used an under-running trolley, and patented the scheme.

In 1884, Daft built an electric railway on one of the piers at Coney Island, and used the track rails for the two conductors. This was repeated at expositions in Boston and in New Orleans.

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FIRST PUBLIC ELECTRIC CARS FOR CITY STREETS

(1880-1888)

In 1881, Siemens and Halske constructed a short commercial road, at Lichterfelde, near Berlin. Two insulated track rails were used in a 180-volt circuit. The wheel tire was insulated from the hub by a wooden band. Later an overhead trolley line, with a rolling contact at the wire, was used. See photograph in Street Railway Journal, Oct. 8, 1904, p. 535. The road is now running as a 600-volt trolley line.

In 1883, Siemens cars were operated in Paris, London and elsewhere, by storage batteries with 5 H. P., 100-volt motors.

In 1883, Siemens and Halske constructed a third-rail, narrow-gauge line, six miles long, the Portrush Railway near the Gaints' Causeway, in northern Ireland, obtaining from a waterfall the power for operating a 250-volt, direct-current dynamo.

In 1884, E. M. Bentley and Water H. Knight operated in Cleveland, Ohio, a road having two miles of underground conduit, placed between the rails. This installation was perhaps the first in which the cars were driven by a series motor, placed under the car floor. Wire-rope and sprocket-chain drive, and later, bevel gearing were tried. The road was operated about one year. See Martin and Wetzler's "The Electric Motor," 1887; Street Railway Journal, Feb., 1889; Bentley, Electrical World, March 5, 1904.

In 1884, Daft operated a pioneer line, 2 miles long, for the Union Passenger Railway Co., between Baltimore and Hampden. Two 3-ton motor cars were used to haul trailers. The over-running trolley and a third-rail contact were both installed. The motors were a series, 130-volt, direct-current, single-geared type.—Electrical World, March 5, 1904.

In 1885, John C. Henry built an electric railroad in Kansas City. There were two cars, each equipped with a 7 H. P., 250-volt, direct-current motor. The overhead trolley wires were 10 inches apart, and two pairs of over-running trolley wheels were held by springs in lateral contact with each wire, the trolley wheels being mounted on a single carriage, and connected with the motors by means of flexible cables. The creditors received 8 cents on a dollar.—Electrical World, Oct. 20, 1910, p. 934.

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In 1886, Van Depoele, working at Minneapolis for the Minneapo-Lyndal and Minnetonka Railway, which had been obliged to dis-inue the use of steam locomotives in the business portions of city, equipped an electric locomotive car for hauling trains.

A summary on public street railways to 1888 shows that cars e generally propolled by horses or mules. Animal power was ex-sive to operate, depreciation was rapid, service was slow, and cient drawbar pull and speed were not available. Experiments out number had been tried with steam engines, electric motors, hot-air and chemical motors, as the motive power for local rail-transportation. Electric street railways were simply an experi-t.

ARLY ELECTRIC STREET RAILWAYS IN AMERICA

	Month	Engineer	Miles	Cars	Motors	Location of Road
	July	Bentley and Knight	2.0	3	1-14 h.p.	Cleveland, Ohio
	Aug.	Leo Daft	2.0	3	1-8	Baltimore, Md.
	Aug.	John C. Henry....	...	2	1-7	Kansas City, Mo.
	Aug.	John C. Henry....	...	1	..	Orange, N. J.
	Oct.	C. J. Van Depoele..	1.0	(4 (1	1-5) 1-10)	South Bend, Ind.
	Oct.	C. J. Van Depoele..	1.0	3	1	Toronto, Ont.
	Oct.	S. H. Short........	0.5	1	1-8	Denver, Colo.
	Jan.	C. J. Van Depoele..	1.5	1	1-20	Minneapolis, Minn.
	June	C. J. Van Depoele..	1.2	2	1-20	Windsor, Ont.
	July	C. J. Van Depoele..	5.0	5	1-10	Appleton, Wis.
	Sept.	C. J. Van Depoele..	2.7	4	1-15	Port Huron, Mich.
	Sept.	C. J. Van Depoele..	1.0	1	..	Detroit, Mich.
	Oct.	F. E. Fisher.......	3.7	4	1-10	Detroit, Mich.
	Nov.	C. J. Van Depoele..	5.0	(9 (3	1-15) 2-12)	Scranton, Pa.
	Nov.	C. J. Van Depoele..	...	12	..	Montgomery, Ala.
	Dec.	Leo. Daft	1.0	1	..	Orange, N. J.
	July	C. J. Van Depoele..	4.0	8	1-15	Lima, Ohio
	Aug.	Leo Daft	4.0	6	..	Los Angeles, Calif.
	Aug.	Leo Daft	...	1	..	Mansfield, Ohio
	Aug.	F. J. Sprague......	...	1	..	St. Joseph, Mo.
	Sept.	F. E. Fisher	...	1	..	San Jose, Calif.
	Sept.	S. H. Short	1.0	2	1-18	Columbus, Ohio
	Nov.	S. H. Short	...	.	..	Huntington, W. Va.
	Oct.	W. M. Schlesinger..	...	.	..	Philadelphia, Pa.
	Oct.	C. F. Adams	4.0	3	..	Wichita, Kansas
	Oct.	C. J. Van Depoele..	7.0	2	2-7	St. Catharines, Ont.
	Oct.	Leo Daft	4.0	18	1-12	Asbury Park, N. J.
	Nov.	John C. Henry	3.0	9	1-20	San Diego, Calif.
	Jan.	Leo Daft	1.0	2	2-7	Ithaca, N. Y.
	Jan.	Bentley-Knight	4.4	.	..	Allegheny City, Pa.

PRACTICAL ELECTRIC STREET RAILWAYS

The first practical electric street railway embodied many of the ntial features of modern practice. It was installed by the Sprague

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Electric Railway & Motor Co. for an 11-mile railway, with 10 per cent grades, at Richmond, Va., and was operated in February, 1888. Energy was furnished from a central station by a 300 H. P. steam engine and a 450-volt direct-current, belted generator, and was transmitted by copper conductors to small cars, each equipped with two 7 H. P. series-wound motors. Thirty cars were in operation by July, 1888.

Mr. Frank J. Sprague in the Transactions of the International Electric Congress, St. Louis, 1904, Vol. III, p. 331, has summarized the features of this now historic road at Richmond.

The Development of Practical Street Railways (1888-1896). Sprague and his associates now proceeded to convince street railway managers that electric power could be made an economical substitute for animal, steam, and cable traction. Sprague electric railway lines in 1890 included Minneapolis, with 100 cars; St. Paul, 80 cars; Cleveland, 99 cars; St. Louis, 80 cars; Tacoma, 56 cars; Pittsburg, 45 cars; Richmond, 42 cars; in all 89 roads and 2080 motor cars.—Electrical Engineer, N. Y., April 30, 1890.

Thomson-Houston Electric Co. absorbed the Van Depoele interests in 1888. Its equipment was similar to that used by Sprague, and included two double-reduction, geared motors per car. One distinguished feature was an excellent controller, for parallel and later for series-parallel operation of motors, in which a magnetic blow-out devised by Elihu Thomson was used. Its first lines were in practical service at Revere Beach, Boston, with one car, July 4, 1888; at Washington, D. C., also at Seattle in 1888; and at Minneapolis in 1889.—Street Railway Journal, 1889, p. 374. Thomson-Houston railway lines in 1890 included Boston, with 127 cars running and 130 ordered; Omaha, 30 cars; St. Paul, 8 cars; in all 61 roads and 431 motor cars. —Electrical Engineer, N. Y., April 16, 1890.

Short Electric Co., which had built lines in Denver in 1885, introduced single-reduction, geared and gearless, motors in 1891.

Westinghouse Electric and Manufacturing Co., of Pittsburgh, entered the electric railway field in 1890 with single-reduction, geared motors.

General Electric Co., of Schenectady, was formed in 1891 as a consolidation of the Thomson-Houston, the Edison General Electric, the Sprague, and other companies. It obtained the patent rights to

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the inventions of Van Depoele, Bentley, Knight, Thomson and Sprague.

General Electric and Westinghouse Companies have fostered most of the important American electric railway developments since 1893. Patent litigation was stopped when the two companies entered into contracts, in 1896 and 1899, which embodied an exchange of licenses for the joint use of the patents of each company. This interchange was advantageous, for it developed a high degree of cooperation in engineering and in manufacture.

Allis-Chalmers Co., which consolidated E. P. Allis & Co., Bullock Electric Manufacturing Co., and others, about 1896, has furnished much of the power-plant equipment, but little of the electric motor and transmission equipments for railways.

Conduit Railways, which avoid overhead wires by placing the trolley conductor in a conduit, as in cable railway systems, were successfully installed and operated in Budapest in 1889, in Washington, D. C., in 1895, and in New York in 1896. Few roads have been built in America, because the construction cost exceeds $60,000 per single-track mile. Conduit roads have been built in Paris, Berlin, Brussels, Vienna, Lyons, Nice, Bordeaux and London.

A SUMMARY OF DISCARDED IDEAS IN ELECTRIC TRACTION

"Count your Failures, not your Successes."

Many engineering ideas were well tried, and then abandoned, between 1885 and 1895, certain apparatus was found to be unsuitable for ordinary electric railway work; and the following have not since been used:

Batteries, primary and storage.

Over-running trolley; rigid or inflexible trolley contact; two trolleys for city streets.

Unprotected third rail; a third rail between track rails; or a third rail on elevated posts.

Conduit systems for ordinary electric railway traffic; and surface contact systems, to avoid the use of the trolley.

Track rails for conducting the positive electric current.

Insulation of track rails from the earth.

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Rail returns, without adequate bonding at the rail joints.

Use of the soil, rivers, or lakes for a heavy return-current circuit; and the artificial grounding of rails.

Magnetic braking, in ordinary railway-train service.

Magnetic adhesion increases between rails and wheels to improve the tractive friction or the economy of operation. See Electric Railway Journal, Dec. 13, 1909, p. 1240; electric gearing, Electrical World, July 21, 1910, p. 166.

Magnetic systems, wherein alternate attraction and repulsion of magnets produced reciprocating motion, to propel the car.

Motors placed above the floor at the end of passenger cars.

Continuous rotation of armature to retain its kinetic energy.

Connection between armature and car axle by means of a magnetic coupling and quill, or a friction clutch; friction wheels, pulleys, grooves, and disks; wire rope, belt, and chain drive; sprockets and links, cranks near the middle of the axle; bevel gear, worm gear.

Long-distance transmission of direct-current power.

Direct-current series systems. Short experimented at Denver, 1885. See: Sperry, A. I. E. E., June, 1892; Dalemont, Electrical World, Oct. 14, 1909; Adams, Electrical Railway Journal, Sept., 1900 p. 810.

Regeneration of direct-current power.

Shunt-wound and compound-wound motors; one motor per car.

Control of motors with liquid resistance,—S. D. Field, about 1886. Control of motors with wire resistance on field magnets. Control of motors by a variation of field coils from series to multiple relation. Field, in 1886; Sprague, in 1888. Control of motor speeds by weakening the field. Control of motors involving two commutators per motor.

Brushes of copper; variation of position of brushes with load or direction of motion; positions other than radial. Relatively large magneto-motive force in direct-current armatures.

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Field poles without field coils mounted thereon. The well-known "W.P." motor of 1891 had consequent poles.

Armatures with a large diameter, and fly-wheel effect. Gearless armatures, mounted on the axle without an elastic coupling to absorb switch and cross shocks, curve thrusts, and track variation.

Motor frames insulated from axles, supports, or rails; motors unprotected from dust, snow, and water of roadbed; motors with unnecessary dead weight, and motor mounting without spring supports.

Mechanical and electrical equipments which were suitable for city or interurban trolley lines, for electric train service.

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REMARKABLE PROPHECY MADE BY THOMAS A. EDISON ON FUTURE USES OF ELECTRICITY

(Engineering News and American Contract Journal, Page 156, March 29, 1884)

Edison, the inventor, indulges in the following prediction: As to the changes which will be effected by electricity within fifty (50) years in the City of New York, I would say that I believe electricity will propel the cars on the street and elevated railroads, light the city within and without its buildings, furnish power for all purposes, work telephones and burglar alarms, deliver the opera, convey parcels, detect and signal fires, operate fire engines and possibly displace animal locomotion for vehicles.

Editor's Note: The Brush Electric Light Company have been making experiments with electric motors at Cleveland, and a railroad has been built for the purpose of testing the motors for tram cars.

A NEW FORM FOR PROPELLING ELECTRIC TRAM CARS

(The Electrical World, Vol. XIX, No. 1, January 2, 1892)

NOT TO SUPERSEDE THE TROLLEY

There is no item of so much interest in connection with the recent discussion as to Mr. Edison's proposed street railway system without trolleys as that which appeared in the "Edison Monthly Record" for December, which is the official organ of the Edison Company. It says:

"The interviews with Mr. Edison, which were recently published by the daily press, concerning his improved system of street car propulsion, seem to have given rise to a widespread impression that the new method is to entirely supersede the present trolley system.

"This is absolutely not so.

"Mr. Edison has devised the new system for roads of heavy traffic, in large cities where the expense of the original installation is warranted by the traffic, and where the trolley system will not be permitted. For instance, the new system would not be applicable, in a commercial sense, to long roads operating less than fifty cars simultaneously. It must therefore be understood that, outside of the large cities, the best system that can be advocated is the trolley.

"In order that a better understanding may be formed as to just what this new system for large cities is, we submit the following particulars, which have been furnished by Mr. Edison:

"The overhead system is entirely dispensed with.

"Cars, trucks, tracks, and roadbed, such as are now in use, are retained, certain changes being made in the joints and cross-ties.

"The power, furnished by 1,000-volt generators, is distributed to reducing apparatus placed in boiler plate manholes at intervals varying in accordance with the number of cars required to be operated. At these various reducing points the current is transformed from 1,000 volts to a pressure of 20 volts, and put in direct communication with the tracks. This limit of 20 volts is fixed in order to prevent horses from being affected by the current. The economy of current is about the same as with the present system of trolley.

"The car motors being wound with uninsulated copper wires, and the pressure of current being so low, there is entire freedom from burning out of armatures, as water can be poured upon the armatures without any ill effect. The problem of producing a perfect rail joint, and the picking up of a heavy current from a mud-covered rail, has been solved in a practical manner. The experimental road at Mr. Edison's laboratory is a quarter of a mile long, with a six (6%) per cent grade and very short curves. It is operated successfully when the rails are entirely buried in mud or in dry sand.

"Mr. Edison is arranging to have the system placed in practical operation on a heavy traffic road in some large city (probably New York) to demonstrate its practicability. This will be done during the coming year."

Considering the great number of roads now being operated by the Edison trolley system, it is safe to predict that the trolley will enjoy its lead for years at least. Should Mr. Edison's most sanguine hopes for his new system be realized, it will, according to the above item, be limited to large cities, which form a small fraction of the street railways of the country.

The electrical fraternity await with interest the details of this new scheme for rapid transit, as many seem to doubt its practicability and economy.

ALTERNATING AND CONTINUOUS CURRENT (AUGUST 16, 1900) DISCUSSION AT PARIS, FRANCE

(American Institute of Electrical Engineers, Vol. XVIII, Page 187)

I think it may bring out the discussion of this subject between the different countries, here represented, more thoroughly if I outline briefly the practice in the country which I come from, viz., the United States of America. For lighting work we started in our large cities with the direct current system as advocated by Mr. Edison. By the way, I once saw a letter from Mr. Edison, written some ten years ago, in response to an inquiry addressed to him asking his views on the relative advantages and disadvantages of the alternating and direct current. His letter intimated that he thought the alternating current was of Satanic origin, that it was a delusion and a snare, and that no good could come out of it. Mr. Ferranti has proven that the contrary is the case, and judging from his remarks and the work of many others, it seems as though the ideas of his Satanic Majesty may yet prevail.

MR. T. C. MARTIN'S INAUGURAL ADDRESS

(Engineering News, June 4, 1887, Page 369)

Mr. T. C. Martin, the new President of the American Institute of Electrical Engineers says in his inaugural address: "The electrical statistics of today are nothing short of colossal. To go no further than our own country, we find an investment and capitalization in simply the leading electrical industries—telegraphy, telephony, electric lighting and electric power—of a sum of, at least, $350,000,000. There are in America about 700,000 miles of telegraph wire. Last year 320,000,000 telephonic conversations were held. Over 150,000 arc lamps, and incandescents verging on 1,000,000 now instruct the public eye that the electric is the light before which all others must pale their ineffectual fires. At least 10,000 electric motors are employed in the most varied industries, and while the electric railways here are carrying passengers at the rate of more than three and one-half millions (3,500,000) annually, the extraordinary increase now going on in that branch promises that the figures will be doubled within the year, with at least from 50 to 75 electric roads in operation. When to these figures we add the thousands of dynamos and vats used in electroplating, the countless electric appliances used in medicine, surgery, and the miscellaneous arts, and the endless variety of electric apparatus for convenience, safety, protection and comfort in the house, office, train or hotel, we arrive at sum totals dealing with which a statistician needs all his ability to mass and classify.

FIRST ELECTRIC STREET RAILWAY

(Engineering News, July 9, 1887, Page 29)

Electric Railways for street passenger traffic seem now to be a fixed fact. In Europe electric street railways are now carrying at the rate of 3,000,000 annually, and probably a little in excess of that number and they are extending. The first built was in Berlin, Germany, 1881, 1½ miles in length. In this country they date from 1885. The following are the places in which they are established in this country. Baltimore, Md., Los Angeles, Cal., Port Huron, Mich., Windsor, Canada, Detroit, Mich., Appleton, Wis., Scranton, Pa., Denver, Col., Montgomery, Ala. In all but one of these the dynamo is driven by a steam engine, but in Appleton, Wis., there is a road of 4½ miles where water power is used. You may recollect that an eminent divine once remarked as an evidence of design in the works of the Creator, that great rivers were placed near great cities. It were fortunate for the purposes of lighting and heating if great water power were placed in the vicinity of large populous districts. It has not yet been sufficiently decided how far power can be carried by means of electricity, nor the size of the conductor and the loss in conducting it. With the short roads now in operation it has been said that the percentage of effect on the car is 50% to 55% of that of the steam engine providing the power. In this respect it is superior to the cable, which is fast superseding horses.

Few of the present engineers recollect the experiment of the old atmospheric railway of Samuda, which ran from Dublin to Kingston, about 1½ miles, successfully for many years; and was later tried in a larger way from London to Corydon and from Paris to St. Germain. It failed and was superseded by the locomotive. It may be that for a moderate distance the atmospheric road may become practicable, but for the present our hopes of a successful motor, especially for city and town roads, are based on electricity. So much at least has been directed to this subject, not only with reference to power, but to light and heating that a new branch of engineering has sprung up and has inaugurated itself into a society like our own as the American Institute of Electrical Engineers. From our knowledge of them and their claims I feel satisfied that they are to be a worthy branch of engineers. In our own country capitalization in electrical industries, telegraphic, telephonic, electric lighting and electric power, amounts to a sum of at least $350,000,000. There are in America about 700,000 miles of telegraphic wire; last year 32,000,000 conversations were held on the telephone; there are over 150,000 arc lamps, and incandescents verging on a million, and at least 15,000 electric motors for fans and sewing machines.

THE ELECTRIC RAILWAY

(Engineering News, July 13, 1889, Page 33)

A lecture was given by Mr. George W. Mansfield, of the Thomson-Houston Electric Company, June 18th, at the first meeting of the newly organized Thomson Scientific Club, of Lynn, Mass., on the subject of the electric railway, which is interesting as reviewing the history of electric progress and showing the exact present status of this rapidly growing business.

Until recently, no important factor in modern civilization has had a greater dearth of information recorded in relation to it, historically and practically, than that obtainable in regard to tramways and street railways. About the year 1680, vehicles were first run upon wooden stringers, and in 1780 or 1790 the first iron rails were introduced. Both proved failures at the time.

Electricity took its start at the beginning of this century. At the same time the introduction of the steam engine and of steam locomotion began and cars were introduced drawn by horses. The Baltimore & Ohio Railroad, the first in the United States, was chartered in 1827 and was intended for operation by horses. Steam was substituted, 1828-30. About the same time the Davidson magnetic engine was invented, and worked as an experiment only, by means of chemical batteries. In 1840 **Davenport**, of Vermont, produced a magnetic engine. In 1850 Dr. Page of Salem, Mass., attempted an electric engine for car propulsion, obtained assistance from Congress, constructed an engine weighing 5 or 6 tons, and operated it by means of chemical batteries, at Washington. All attempts, however, to use the chemical battery for the source of power have failed. During all this period electric power lay dormant and the world saw the marvelous development of steam power, with which every one is familiar. Before this time, to travel from Boston to New York required a journey of four or five days. It is now accomplished in six hours. This country alone has constructed over 150,000 miles of steam railroads, and has built 12,000 miles in a single year.

The necessity of getting from one immediate locality to another has increased as the growth of cities has continued. To meet this need, steam has been again and again tried, but has failed. In 1860 the Gramme ring was invented, and this, in connection with the Siemen's armature, has enabled electricity to be generated in sufficient quantity and so cheaply as to make the succeeding improvements practically successful.

As soon as electric power became practicable, all the intelligence and genius of the civilized world, which before had been developing steam power, turned its attention to the new power, and began developing it in the direction of the most pressing wants. Lights were poor, gas dear and unsatisfactory. A better light was needed. Hence from 1870 to 1880, all experiments were conducted with a view of utilizing the electric light, and with what a marvelous result! No quarter of the civilized globe is unsupplied with the electric light.

In 1832 the first horse railway was introduced, being a line from New York to Harlem. Today there are 25,000 street cars in use, and 150,000 horses. In 1856 the first horse car was introduced in Boston, on a line from Cambridge to Bowdoin Square. Since that date Boston alone has built 218 miles of track, and now employs 8,000 to 9,000 horses and 1,200 to 1,500 cars. There are 800 cars running every day. The West End Street Railway of Boston, has become, by consolidation, the largest street railway in the world. It carries 110,000,000 passengers in a year, or twice the number of the entire population of the United States, and more than the number carried by the combined steam roads of the State, which was 89,000,000. In New York, the street railways carry 325,000,000 and this in addition to 180,000,000 carried by the elevated roads. The speaker predicted that single electric-power stations would be built, in the near future, producing 10,000 to 20,000 H. P., or enough to do all the lighting and transportation service of a city. In touching upon the supplying of the electric power, where wires must be used, it was said that the underground conduit was an absolute failure. Water, mud, and the debris from the street made the open conduit entirely impracticable, owing to short circuiting. The Boyleston Street conduit constructed at a cost of about $75,000 had been abandoned. The absolutely only successful method in use today was that of the overhead wire and single trolley system. The right has been granted in Boston to use this method throughout the city. One hundred and twenty-five cities have granted this right already.

As to cars and motors, it was said that no motor ever had to withstand such natural and mechanical difficulties as the street railway motor. Electricians had always considered that an electric motor ought to be kept dry, to be effective. But now it has got to be used under a car near the street level, where its use subjects it to unforeseen rough treatment. How to construct a motor to withstand such use, mechanically and electrically, is a new problem to be solved. Such motors are now under construction, and are to be capable of withstanding the test of a stream of water from a hose, and to operate perfectly under such a condition. To relieve the congestion of cities, due to the concentrating of population in the centers, some improved means of transportation or circulation must be supplied. Horses are expensive, and can operate but 5 or 6 hours out of the 24. The solution is in the use of the electric motor, operating for 24 hours a day, if required, to supply these needs. The Thomson-Houston Company has 45 to 50 electric roads now either equipped or under contract, while, it has been recently stated, 1,000 cars are now being equipped in this country, for electric power. The largest street railway system in the world is now considering the question of equipping its entire plant with the electric power. When one such line has completed its adoption, there will be an avalanche of roads hastening to follow. The electric motor, like the electric light, has met the needs of the world and has been approved. The inventive talent and brains of the country are today largely, if not principally, turned in the direction of the development of electric power. By means of electricity, in a quantity too small yet to be measured by instruments, we can talk from Boston to Philadelphia, in a whisper, and be understood, and the voice even recognized. What the same agency will accomplish in transportation and in the endless application of the useful arts, while not more wonderful, cannot be imagined, but it will ork out results in accordance with the conflicting conditions of ractical life.

GROWTH OF THE ELECTRIC RAILWAY

(Engineering News, September 7, 1889, Page 218)

Mr. George W. Mansfield read before the National Electric Light ssociation at its Niagara Falls meeting, an interesting paper on elecic railways, which we abstract as follows:

"The steam railroads of the United States, with nearly an equal umber of cars and 42 times more road than the street car lines, cared only a quarter as many passengers. The horse cars of the city f New York carry 199,491,735 passengers, almost half as many as re carried by all the steam roads in the United States. If to this umber are added those carried by the elevated roads we have a total f 371,021,524, or almost as many passengers are carried in New York ity alone as are annually carried by all the steam roads in the whole nited States. The street railways of the State of Massachusetts rry over 44,000,000 more people than all the steam roads in that ate. One road alone, the West End of Boston, carries nearly),000,000 more than all the steam roads combined.

"If we figure for each car 6 H. P. of electric energy, it will give a ugh idea of the size of an electrical central station needed to opere all the cars. In New York City, dynamo capacity of 13,800 H. P. ould be demanded, in Boston 9,504 H. P., and so on. This is desned to come. In Boston it has come, and a station of approximately 000 H. P. is already in the hands of the engineers.

"Electricity shows already the steady, vigorous growth that initably will result in its complete supremacy for street car purposes. he following table shows the increase of electric railways and this es not include the remarkable contract just entered into by the est End road:

	Number Elec. Railways	Miles of Track	Number of Cars
1885	3	7.5	13
1886	5	28	39
1887	7	29	81
1888	33	130.5	265

Jan. 1-July 1, 1889	19	113	174
Building July 1, 1889	42	267	364
Total	109	575	936

"An interesting comparison is also afforded in the following table:

	1870	1880	1890 Estimated
Total H. P., both water and steam, engaged in the whole manufacturing industry of the U. S......	2,346,142	5,410,837	10,000,000
Total H. P. engaged in the electric lighting and power industry....	....	1,000	500,000
Total H. P. engaged in electric railway industry	....	....	30,000

EARTH CURRENTS

(The Electrical World, May 20, 1893, Page 369)

A very interesting phenomenon and one that has received considerable attention from various experimenters, is that of earth currents. A variety of theories have been advanced as to the cause of these currents, careful study has been made of their nature and strength and the frequency of the intervals at which they manifest themselves, and it has even been proposed to store up their energy for commercial use. Mr. J. Kennedy Gibson has made a series of interesting experiments upon the subject on one of the Java-Australian cables, the results of which are given elsewhere in these columns. His observations differ in many respects from those made in other quarters of the globe. In all his experiments the diurnal variation seems to be fairly uniform, the times of maxima and minima agreeing in a marked manner. On the Atlantic cables it has been found that there are two complete alternations in twenty-four hours, while on the Java-Australian cable there appeared to be but one of about thirteen hours' duration, while during the remaining period the currents are weak and variable. The slope of earth-current variation does not seem to coincide with that of the tidal lines. Mr. Kennedy is not inclined to accept the hypothesis that the earth current variations are due to either the sun or the moon individually, but suggests that they are more probably due to the combined influence of the sun and the moon, and are also affected by thermometric and barometric variations.

AN ELECTRICAL PIONEER

(The Electrical World, January 9, 1892)

We have been fortunate in being able to give to our readers this week a portrait of Mr. George F. Green, of Kalamazoo, Mich., whose electric railway patents recently issued have attracted so much attention, as well as a facsimile reproduction of one of his early drawings, made nearly 20 years ago. This shows in a rough but striking way the system which he intended to employ.

It appears from the history of the case that the invention had long been in Green's mind. His experiments in electrical appliances date back as far as the year 1856; but it was not until 1875 that he produced a little model electric road, notice of which has already been given in our columns. The larger model was not built until 1878 or 1879. In the latter year, August 19, this patent was applied for. Although the batteries as a source of power were foremost in his mind even then, to judge at least from the original specification, he clearly appreciated the use of the dynamo in connection with the work.

The principal interference encountered in the Patent Office was, of course, that with Mr. S. D. Field, and the examiners in chief awarded priority to Green, which decision, after various vicissitudes, has been reinforced by the issue of the patent. The litigation in the Patent Office as a whole was particularly severe, the early claims of Pinkus and others being urged by the examiners against Green; and, of course, this ground may after all have to be gone over again before the patent is finally established. But as it stands the issue of that document may be regarded as a victory for a most ingenious and meritorious invention, whatever may be its immediate fate

Mr. Green furnished the connecting link between the crude early experiments and the modern electric railway. A glance at the original drawing, as shown in facsimile in our figure, shows albeit crudely, his intention of using either overhead or rail conductors, although the trolley wire is shown suspended from the bottom instead of the top, as in modern installations. Of the motor system unfortunately no details are given.

The electric railway, like many other important inventions, has been a growth of years, and it is sometimes very difficult to say at what time any given step was taken for every detail. There has been apparently an old suggestion followed by a period of experimentation and the final evolution of a practical form. From an historical as well as from a legal point of view, the genesis of the modern electric railway is no easy matter to trace. One has to trace its origin in this country back to the root of the period of electrical invention that produced in the hands of Davenport the earliest crude electric railway and from Morse the telegraph.

What were mere suggestions thus grew a decade later to be the experiments, and then came the period of the Civil War, when invention, except in military circles, was almost at a standstill; then the working model of Green, the experiments of Field, and a little later, after the final stimulus had been given by the Siemens electric road in Berlin, the work of a group of modern inventors that has given us now more than 400 electric railways. The ill fortune of Green in the Patent Office unfortunately has kept his labors from the knowledge of the public until very recently, but now that they have been clearly seen he should be accorded a worthy place among the electrical pioneers of whom this country has produced so long and noteworthy a line.

PROGRESS OF ELECTRIC STREET RAILWAYS

(Engineering News, July 16, 1887, Page 33)

Short electric railways are multiplying very fast. In our issue of May 28, 1887, we published a list of such railways in the United States. Quite recently the following have been announced:

Newport, Ky., horse road changed to electricity.
Findlay, O. Four mile road building.
Lakeside, O. Three mile road building.
Mansfield, O. Four and one-half mile road building.
Port Huron, Mich. Changing from horses to electricity.
San Francisco, Cal. Three mile road, horses to electricity.
St. Paul, Minn. Two mile line opened July 4, 1887.
St. Joseph, Mo. Road running 20 cars, to be ready this Fall.
Worcester, Mass. Lake Quinsigamond Road, four miles, changed from steam to electricity.

Allegheny, Pa. Four mile road to be ready October 1, 1887.
Asbury, Park, N. J. Three mile road, 15 cars.
Birmingham, Ala. Two mile road.
Jamaica, Long Island. Ten car.
Lima, Ohio. Three mile road.
St. Catharines, Ont. Two mile road.
Fulton Street, N. Y. One mile road.

In all, it is stated in a carefully prepared article which appears the "New York Evening Post" where we find the above list, that arly forty electric railways will be running in this country before inter. We think there are strong reasons to believe that the plant ed on every one of these lines will be very materially improved, th as respects weight, cost and efficiency in the near future, yet the x firms who now take the most prominent part in supplying these ants are plausibly stated to be overcrowded with orders. It is aprent that the age of electricity has come to stay, and that wide as its use now, it is but a fraction of what it will be within a few ars.

RAPID GROWTH OF ELECTRIC STREET CAR

(Engineering News, October 25, 1890, Page 374)

The Buffalo meeting of street-car officials shows in a very marked gree the rapid rate at which electricity is supplanting horses as a otor on our public streets. It is true that out of 3,150 miles of track 56 cities of over 50,000 inhabitants only 260 miles are as yet opered by electricity as compared with 255 miles operated by cable. ut the nature of the exhibits and that of the majority of the papers ad at this convention show that electricity is coming. The electric rs of the various prominent corporations in this line of manufacre, an electric snow-plow and snow-sweeper and a variety of novels of this nature, devised to meet the demands of street traffic, sufiently prove the live and increasing interest of inventors and manucturers in this especial line. The application of electric power is t comparatively new, and some inherent difficulties in the way of reet obstruction by poles and wires, or of dead load in the shape accumulators and motors, have yet to be overcome; but electricity evidently here to stay, and it now amply meets the requirements many locations and conditions of traffic.

OPERATIONS OF THE WEST END STREET RAILWAY CO., BOSTON, MASS.

1891.	ELECTRIC.				
	APRIL.	MAY.	JUNE.	JULY.	AUGUST.
Gross receipts	$134,321.00	$144,638.00	$145,319 00	$144,553.00	$136,246.00
General expenses	8,193.00	7,796.00	7,465 00	6,956.00	6,027.00
Maintenance expenses	0,795 00	8,891.00	8,078.00	11,990.00	12,498.00
Transportation expenses	37,653.00	36,552.00	31,556.00	31,895.00	31,123.00
Motive power	30,194.00	30,924.00	26,360.00	26,399.00	25,630.00
Total operating expenses	85,835.00	84,163.00	73,459.00	77,249.00	75,278.00
Net earnings	48,487.00	60,475.00	71,860.00	67,304.00	60,968 00
Miles run	394,459	376,321	360,567	377,191	363,836
Ratio of mileage	26.68	25.58	25.15	25.19	24.92
Per cent. operating expenses	63.36	58.18	50.55	53.44	57.13
EXPENSES PER MILE RUN.	CTS.	CTS.	CTS.	CTS.	CTS.
Motive power per mile	07.65	08.22	07.31	07.00	07.04
Car repairs per mile	01.39	01.33	01.18	01.17	01.57
Damages per mile	00.75	00.89	00.16	00.12	00.23
Conductors and drivers per mile	07.33	07.36	07.25	06.92	06.85
Other expenses per mile	04.63	04.56	04.47	05.27	05.00
Total expenses per mile	21.75	22.36	20.37	20.48	20.69
Earnings per mile run	34.05	38.43	40.30	38.32	37.45
Net earned per mile	12.30	16.07	19.93	17.84	16.76

1891.	HORSE.				
	APRIL.	MAY.	JUNE.	JULY.	AUGUST.
Gross receipts	$344,396.00	$374,606.00	$404,225.00	$409,878.00	$392,474.00
General expenses	22,514.00	22,682.00	22,218.00	20,657.00	18,160.00
Maintenance expenses	22,692.00	17,748.00	18,560.00	27,228.00	18,669.00
Transportation expenses	114,001.00	110,154.00	106,836.00	108,732.00	105,953.00
Motive power	117,740.00	118,972 00	116,211.00	116,271.00	113,351.00
Total operating expenses	276,947.00	269,556.00	263,825.00	272,888.00	256,133.00
Net earnings	67,449.00	105,049.00	140,399.00	136,990.00	136,341.00
Miles run	1,083,887	1,094,683	1,073,218	1,120,377	1,096,376
Ratio of mileage	73.32	74.42	74.85	74.81	75.08
Per cent. operating expenses	80.62	71.95	65.27	66.58	64.52
EXPENSES PER MILE RUN.	CTS.	CTS.	CTS.	CTS.	CTS.
Motive power per mile	10.86	10.86	10.83	10.38	10.33
Car repairs per mile	00.93	00.60	00.61	00.61	00.03
Damages per mile	00.78	00.37	00.15	00.06	00.10
Conductors and drivers per mile	08.28	08.24	08.25	08.23	08.10
Other expenses per mile	04.70	04.55	04.74	05.07	04.81
Total expenses per mile	25.55	24.62	24.58	24.35	23.37
Earnings per mile run	31.77	34.22	37.66	36.58	35.80
Net earned per mile	06.22	09.60	13.08	12.23	12.43

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*In February, 1891, President D. F. Henry, of the Federal Street and Pleasant Valley Passenger Railway Company of Pittsburg, Pa., made a report of the operation of the company for the preceding six months, in which was embodied some interesting information in this line. We quote from it as follows:

Passengers carried, six months, 3,370,531; receipts, $168,526.55; mileage. 31 cars, averaging each 108 miles per day, total daily average 3,348 miles. Cost per mile:

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Conductors and motormen	per mile,	6.80	cents
Motor and electric repairs	"	1.68	"
Mechanical repairs	"	1.14	"
Motive power	"	1.54	"
Overhead system	"	0.45	"
Maintenance of way	"	1.08	"
General expense	"	0.88	"
Stables	"	0.46	"
Officers and salaries	"	0.84	"
Interests	"	2.71	"
Tolls	"	0.25	"
General labor	"	2.43	"
Total		20.26	cents

as total cost per mile of operating expense, fixed charges, salaries and interest, as against receipts per car-mile of 27.55 cents; showing net earnings per mile of 7.29 cents.

Separating the above into strictly operating expense and fixed charges, we have operating expense, 12.74 cents per mile; and in comparing the same with the cost of operating the horse line, which was 10 cents per car-mile, we must remember that we then paid but one man on a car, where we now pay four, or 3 cents per mile, against 6.80 cents now. This increased cost per mile for conductors and motormen is a necessary adjunct of rapid transit, and is not peculiar to the system. Allowing for this, we have a difference of 1.04 cents per car-mile in favor of electricity as against animal power.

I call attention to the fact that we have one of the most difficult roads in existence to operate, with streets having over one hundred curves, many of which have a short radius, and with heavy grades, leaving but little straight and level roadway. We have also six steam and six cable railway crossings.

President John N. Beckley, of the Rochester Railway Company, at a recent meeting of the Street Railway Association of the State of New York, gave the following as the result of the experience of his company.

In the month of May last the Rochester Railway Company operated 44 18-foot vestibule electric cars. The gross receipts from passengers riding on these cars during the month were $37,053, or 23.15 cents per car-mile for a mileage of 159,567 miles. The total expense of operation of these cars for that month was $18,332, thus leaving a net profit of $18,721. The total cost of operation per car-mile was 11.4 cents, and the profit per car-mile was therefore 12.11 cents. It may be observed in passing that the operating expense was a trifle under 50 per cent of the gross receipts. The cost of operating was divided as follows:

Motive power	2.8	cents
Car repairs	0.7	"
Conductors and motormen	4.9	"
Other expenses	3.0	"

During the same period the company operated 62 horse cars, all of them without conductors. Most of the horse cars were one-horse or bobtail cars. The total cost of operating the horse cars, without conductors, during this

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period was about 10 cents per car-mile, but the total receipts per car-mile were but little above 12 cents.

In the month of June the Rochester Railway Company operated 54 electric cars and 60 horse cars. The electric cars earned each per day $23.60, or 22.7 cents per car-mile, and the total expense of operating them per day was $10.50, or 11.07 cents per car-mile. The cost of operation per car-mile was divided as follows:

Motive power	2.40	cents
Car repairs	1.00	"
Conductors and motormen	5.66	"
Other expenses	2.01	"
Making a total per car-mile of	11.07	cents

The cost of operating the horse cars during the same month per car-mile was 11.06 cents, and they earned 14.37 cents per car-mile. My experience in the operation of street railroads has convinced me that the most economical system of operation is the electric system. I have not, in the statements which I have now made, taken into consideration the greater fixed charge in the operation of an electric railroad as compared with a horse railroad, due to the much greater cost of the former; but in arriving at the conclusion which I have above expressed, due consideration has been given to this element of increased cost. We know that when a horse railroad is changed over and operated by electricity the receipts are very largely increased. It is safe in any case to say that the increase in gross receipts will be at least 15 per cent, and the average increase is probably as high as 30 per cent. Some of the increase is undoubtedly due to the greater mileage which the cars make, and still more is due to the cleaner, more rapid and more comfortable transportation of the people.

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STATISTICS ON EARLY ELECTRIC STREET RAILWAYS

By Henry M. Watson

(The Engineering Record, November 21, 1891, Page 396)

Before American Street Railway Association, Pittsburgh, Penna.

(Up to September 15, 1891)

As an elaboration of the item on electric railways, recently published by us, the following statistics, given by Henry M. Watson in his presidential address at the recent Pittsburgh meeting of the American Street Railway Association, will prove interesting. The figures have been compiled from returns made by street railway companies in the United States to the middle of September, and are believed to be as reliable as it is possible to make them:

Total number of miles	1,103
Number of miles operated by animal power	5,443
Number of miles operated by electricity	3,009
Number of miles operated by steam motors	1,918
Number of miles operated by cable	660
Total number of cars employed in street railway traffic	36,517
Number of cars operated by animal power	25,424
Number of cars operated by electricity	6,732
Number of cars operated by cable	3,317
Number of cars operated by steam motors	1,044
The number of horses employed	88,114
The number of mules employed	12,002
The number of steam motors	200
Number of companies operating street railway lines	1,003
Number of companies operating by animal power	537
Number of companies operating by electricity	412
Number of companies operating by cable	54
Number of companies engaged in building new lines, about	75

Since November, 1890, the number of horses employed on street railway lines has fallen from 116,795 to 88,144; that is, 28,681 in one year. According to the official figures for the month of October, 1891, Philadelphia leads with 510 miles of single track; and after the Quaker City comes Chicago with 452 miles, New York with 289 miles, Brooklyn 285, Boston with 283, St. Louis 275, Baltimore 207, San Francisco, 205, Cleveland 192, Cincinnati 180, Pittsburg 168, Kansas City, 141, New Orleans 139, Louisville 132, Buffalo 110, Minneapolis 101, Los Angeles 99, Detroit, 94, Birmingham, Ala., 92, St. Paul 90, Washington 85.

The official figures of the census just completed show that in December, 1889, 476 cities and towns possessed rapid transit facilities; and it is now difficult to find any town of 5,000 inhabitants without one or more street railways.

FIRST ELECTRIC CARS IN BOSTON, MASS.

(Engineering News, October 22, 1887, Page 290)

THE SPRAGUE ELECTRIC MOTOR ON BOSTON STREET RAILWAYS

The first public trial of the new Sprague electric car, which is understood to have been taken up by the West End Street Railway Company, and which we illustrate this week, was had Monday afternoon, October 10. A short test was made in the car-house of the Cambridge Railroad on the previous Saturday evening, and the storage batteries were recharged by wires from the Cambridge Electric Light Company. At precisely 3:30 p. m., the appointed hour, the car was started, with forty-four gentlemen aboard, including the presidents of the Metropolitan and Cambridge roads, representatives of the West End Company, engineers, electricians and representatives of the Boston press The car ran without the slightest apparent difficulty, and at about the ordinary speed of a street car, to the Charles River bridge, thence to Harvard Square, a distance of nearly 3 miles, and from there to the Mechanics' Exhibition in Boston, about 4½ miles, in about 45 minutes' time, including several delays. On this trip hills of about 3 per cent grade were readily climbed, and the car stood the racket without apparent detriment of running for some distance off the track, as the flanges jumped the track owing to defects in the latter or some other cause. The entire trial was fairly comparable to ordinary running conditions, and was, to all appearances, successful. The motors, two in number, weighing together 1,400 lbs., and geared directly to the axles as shown, the connections with the car body being a yielding spring attachment which prevents a sudden strain from injuring the gears. The storage battery is of the Julian form and consists of 120 cells weighing about 30 lbs. each, or a total weight of 3,600 lbs., which, added to that of the motors, equals a total additional weight of the electric apparatus to the car of 5,000 lbs., or 2½ tons. The car is especially built for the purpose, and does not differ from the common closed street car except that the inside floor is raised by a step of 6 inches above the platform level, which enables a stronger form of framing to be employed than in the ordinary car. The storage cells are placed under the seats, access being had to them from the outside by hinging the boards forming the sides of the car. In the car house are long tables at the level of the receptacle thus formed, upon which the batteries can be easily slid upon lubricated iron ways for recharging.

The New York test of this car was at a maximum speed of 12 miles per hour, with 15 persons on board, and power sufficient to climb a 6 per cent grade. As this electric power is so new to most engineers engaged in other branches than that of electricity, it may not be amiss to state how such power is figured. The analogy is most perfect between water power and electric power. Electric pressure is measured in volts, and is cumulative as the cells are connected for street car propulsion. That is, each cell has a potential of about 2 volts and the 120 cells would therefore have 240 volts of potential. The current corresponds to quantity (as of water) used, and is measured in units called amperes. The current flowing from a storage battery depends upon the amount of power required to move the car. A small instrument, called an ampermeter, is fixed beside the car driver, which shows the current being used at each instant. As this varied between 15 and 18 amperes it should, by a simple calculation, be the horsepower that was exerted to have been between 5 and 6. For, taking the current at 15 amperes, multiplying by the number of volts 240, gives 3,600 volt amperes and dividing this by 746, the number of volt-amperes equivalent to a horsepower, 5 is obtained. The car will use in seven hours' running about 20 per cent of the electricity stored in the cells. The charging current was about 20 amperes and as the car expended the energy at about the same rate it requires about the same time to recharge this amount. As the car was geared for power, that is, to climb 6 per cent grades with a full load, the speed was limited to about that of a common car.

The driver controls the movements of the car by means of a vertical lever attached to each dashboard and which, moved to the right, throws succeeding sections of the battery into connection with the motors, and to the left cuts them off. The car is lighted by chandelier and end incandescent lights, and fitted with an alarm gong also operated by the electric current.

The engineering field opened by the commercial success of the electric motor on street railways alone, is a very large one, and we shall revert to this subject more fully in early issues. The time is near at hand, if it is not now, when every engineer who would keep abreast with the times in the discharge of his duties, must have a clear understanding of the elements of electrical engineering at least. A great number of people are now working over the problem of electric street car propulsion, some of whom, who have made little noise in the public press as yet, have devices of the highest promise. We think it extremely probable that very much better than this performance will be done ere long, but in the meantime, we may well be thankful that so much has been already accomplished.

BOSTON, MASSACHUSETTS

(Engineering News, August 22, 1891, Page 155)

The cost of operating the electric cars on the West End Street Railway in Boston averaged 20.37 cents per car-mile during the month of June. The operating expenses of the horse cars operated by the company during the same time averaged 24.58 cents per car-mile. A still greater difference was shown in the earnings, which averaged 42.71 cents per mile for electric cars, and 36.85 cents per mile for the horse cars. This left net earnings per car mile of 22.34 cents for the electric cars, and 12.27 cents for the horse cars. The total mileage of electric cars during the month was 300,568 miles; and the total horse car mileage was 1,073,217 miles. For the three months ending June 30, the percentage of operating expenses to gross earnings was 56.23% for the horse cars, and 72.7% for the electric cars. In our editorial columns we have compared the earnings and expenses above with those of passenger trains on ordinary railways.

BOSTON, MASSACHUSETTS

(Engineering News, February 15, 1890, Page 145)

The West End Street Railway Company, of Boston, Mass.

The West End Street Railway Company of Boston, Mass., operates 253.20 miles of line. During the year ending September 30, 1889, a distance of 525,366 miles were run by electric cars, and 16,048,465 miles with horse cars. The electric system is to be introduced on all the company's lines. It is to be regretted that the conduit system tried on one line proved unsatisfactory, and has been abandoned. The overhead wire system is not suitable for city streets. The number of passengers carried during the year was 104,243,150 an average of 6.29 passengers per mile. The equipment consists of 1,794 horse cars and 47 electric cars. The number of horses is 7,728. The gross earnings amounted to $5,249,902.62; operating expenses, $4,099,037.00. Net earnings $1,150,865.62.

FIRST ELECTRIC CAR OF MONTGOMERY, ALABAMA

(Engineering News, June 23, 1887, Page 16)

Montgomery, Alabama, on June 23, 1887, the Capital City Street Railway Company began operating its cars by electric motors. One motor can pull three loaded cars at a speed of 10 to 15 miles per hour. There are four lines, aggregating 15 miles, a considerable portion being double track.

ELECTRIC RAILWAY PROGRESS

(The Electrical World, April 9, 1892, Page 249)

It is an interesting fact that out of 16 cities of over 200,000 population in the United States, 14 or over 87 per cent, are using the electric railway system, or equipping roads with the system. And out of 42 cities with populations ranging from 200,000 to 50,000, all but one are using the electric railway system. Philadelphia, New Orleans, and New Haven have not yet adopted the electric railway. These cities, however, will probably be using the system before the end of the year. At the end of last February there were 187 street railways in operation in the United States using the Thomson-Houston system, against 183 the previous month. The number of motor cars used by these railways was 2,941, against 2,790 the previous month. There were 35 roads under contract March 1 to be supplied with the Thomson-Houston electric system, which includes 1,379 motor cars (2,758 motors), against 611 motor cars (1,222 motors) under contract January 15th.

The total number of roads in operation and under contract with the Thomson-Houston Company March 1 was 222, against 214 roads January 15, 1892. The total number of cars for roads in operation and under contract with the Thomson-Houston Company March 1 was 4,319, against 3,406 January 15, 1892. The West End Street Railway Company is now using 292 motor cars or 584 Thomson-Houston motors, and is under contract for 500 more motors. The Lynn & Boston Railway Company is under contract for 360 motors.

GAS-DRIVEN STREET CARS IN ENGLAND

(The Engineering Record, August 1, 1896, Page 157)

There has just been opened at Blackpool, England, a tramway operated by gas motors, practically similar to those in operation in

Dessau and Dresden, Germany. The engine, which is on the Otto cycle, is of 15 horsepower, and is installed under the longitudinal seat on one side of the car. The gas is obtained from the town mains, and is compressed at the company's works. Receivers are provided to store gas sufficient to run the car for 8 miles. The track lies to a considerable extent along the country road, and there are some steep gradients. The cars are operated at 8 miles per hour, although they are said to be capable of 12 to 14 miles speed. The cars are double-decked, and capable of seating 40 passengers.

STREET RAILWAY STATISTICS FOR FIFTY CITIES.

CITY.	STATE.	POPULATION.	AREA.	Street Car Trackage.	Gross Receipts from Operation.	Passengers Carried.	Pass. Carried per day.	Rides per Capita.	Amt. Paid per Capita per Annum.	Cars in Constant Operation Possible to be Supported	Cars Reported.	*Box Cars.	Open Cars.
New York City	N. Y.	1,515,301	40.2	276	$10,941,175.89	218,823,517	599,516	144	$7.22	1,499	2,373	1,912	461
New York City	N. Y.	Elevated.		90	9,291,681.60	185,833,632	509,133	123	6.15		921		
Philadelphia	Penn.	1,046,964	129.4	455	7,481,954.27	164,458,842	450,572	157	7.15	1,126	1,691	930	761
Brooklyn	N. Y.	806,343	26.5	275	4,833,945 06	101,705,821	278,646	126	5.99	697	2,486	1,344	1,142
Brooklyn	N. Y.	Elevated		89	2,504,538.70	49,429.228	135,423	61	3.05		373		
Boston, †	Mass.	640,000	35.3	269	5,685,299.04	114,991,678	315,046	179	8.88	775	2,045	1,002	1,043
Buffalo	N. Y.	255,664	39.	59	761,344.86	16,425,983	45,003	64	2.97	113	207	143	64
Pittsburg. ‡	Penn.	238,617	29 6	146	1,621,501.94	33,241,793	91,073	97	4.71	228	521	287	234
Rochester	N. Y.	133,806	15.6	64	578,658.47	11,370,134	31,151	85	4.32	78	192	127	65
Providence	R. I.	132,146	19.	58	935,630 85	18,473,724	50,613	139	7.08	127	341	227	114
Allegheny City	Penn.	105,287	7.3		See Pittsburg.								
Albany	N. Y.	94,923	11.	31	254,479.90	4,787,847	13,117	50	2.65	33	116	105	11
Syracuse	N. Y.	88,143	20.	61	306,732.40	6,330,158	17,343	72	3.48	43	132	99	33
Worcester	Mass.	84,655	34.	22	232,474.66	4,851,574	13,292	57	2.73	33	73	39	34
Lowell	Mass.	77,696	11.2	27	209,830.45	4,183,392	11,461	54	2.70	29	105	57	48
Scranton	Penn.	75,215	25.	29	146,801.00	2,988,403	8,187	40	1.95	21	52	29	23
Fall River	Mass.	74,398	11.	16	154,747.62	3,143,212	8,611	42	2.08	22	66	30	36
Troy, §	N. Y.	83,388	5.2	27	356,867.68	6,244,276	17,107	102	5.86	43	120	61	59
Reading	Penn.	58,661	7.	13	130,648.63	3,175,979	8,701	54	2.23	22	79	44	33
Lynn, ‖	Mass.	150,420	10.6	59	601,094.32	11,637,089	32,704	77	4.00	82	252	116	136
Lawrence	Mass.	44,654	6.7	11	79,250 50	1,585,506	4,344	36	1.77	11	37	19	18
Springfield	Mass.	44,179	34.5	21	180,990.50	3,628,008	9,940	82	4.09	25	74	42	32
Utica	N. Y.	44,007	6.	32	131,584.26	2,676,790	7,333	61	2.99	19	85	67	18
Manchester	N. H.	44,126	40.	15	46,627.33	888,990	2,436	20	1.05	7	25	13	12
New Bedford	Mass.	40,733	19.	16	143,000.44	3,235,116	8,864	79	3.51	23	72	35	37
Erie	Penn.	40,634	7.	15	74,603.50	1,553,718	4,257	38	1.83	11	38	21	17
Somerville	Mass.	40,152	4.		See Boston.								
Cambridge	Mass.	70,028	5.8										
Portland	Maine.	36,608	3.5	10	136,010.53	2,728,935	7,614	75	3.72	20	54	36	18
Holyoke	Mass.	35,528	12.5	7	33,884.99	693,419	1,900	20	.96	5	18	9	9
Binghamton	N. Y.	35,093	10.	32	75,032.65	1,662,587	4,555	48	2.14	12	46	28	18
Yonkers	N. Y.	31,945	12.5	6	11,706.10	234,122	641	8	.37	2	14	12	2
Salem	Mass.	30,735	7.	41	228,503.73	4,475,950	12,263	145	7.43	31	122	59	63
Long Island City	N. Y.	30,396	10.	38	151,350.28	2,936,847	8,046	97	5.00	21	114	75	39
Elmira	N. Y.	28,070	7.2	14	33,144.06	662,882	1,876	24	1.20	5	31	21	10

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City.	State.	Population.	Area.	Street Car Trackage.	Gross Receipts from Operation.	Passengers Carried.	Pass. Carried per day.	Rides per Capita.	Amt. Paid per Capita per Annum.	Cars in Constant Operation Possible to be Supported	Cars Reported.	* Box Cars.	Open Cars.
Chelsea	Mass.	27,850	2.5		See Lynn.								
Pawtucket	R. I.	27,502		9	$48,259.49	964,814	2,643	35	1.76	7	23	23	
Haverhill	Mass.	27,322	24	14	56,801.94	936,170	2,565	34	2.08	7	38	21	17
Brockton	Mass.	27,287		18	102,647.25	2,210,706	6,057	81	3.76	15	46	21	25
Auburn	N. Y.	25,887		6	11,833.16	236,663	648	9	.45	2	16	12	4
Taunton	Mass.	25,389		8	37,560.31	767,292	2,102	30	1.48	6	23	13	10
Newton	Mass.	24,357	22	6	16,685.02	348,597	955	14	.68	3	17	9	8
Hempsted	N. Y.	23,517			No Report.						-		
Newburg	N. Y.	23,263		5	24,794.85	495,897	1,359	21	1.05	4	11	11	
Malden	Mass.	22,984			See Lynn.								
Poughkeepsie	N. Y.	22,836		4	16,954.52	268,622	736	12	.74	2	9	9	
Cohoes	N. Y.	22,432	55		See Troy.								
Fitchburg	Mass.	22,007		6	30,961.92	509,143	1,395	23	1.41	4	13	6	7
Oswego	N. Y.	21,826		3	6,494.13	134,536	369	6	.30	1	5	5	
Lewiston	Maine	21,668		10	21,309.74	426,195	1,168	20	.98	3	22	15	7
Gloucester	Mass.	21,262		6	34,436.23	650,692	1,783	31	1.61	5	18	8	10
Kingston	N. Y.	21,181		3	29,044.70	446,770	1,224	21	1.37	3	8	8	
Woonsocket	R. I.	20,759		6	17,911.75	358,235	982	18	.86	3	10	10	
		6,978,924	716.6	2,428	$18,810,786.22	997,813,484	2,734,754	2,811	139.79	5,228	[illegible],134	7,160	4,680

* This includes motor cars not designated as box or open.

† Based on the aggregate population of Boston and suburbs through which the West End Street Railway cars run.

‡ Based on the aggregate population of Pittsburgh and Alleghany City; a total of 343,904.

§ Based on the aggregate of Troy and Cohoes.

‖ Based on the aggregate population of Lynn and towns through which the Lynn and Boston Street R. R. cars run.

General Note.—The number of cars reported in each city is much in excess of the number in actual service. This fact is due to the large number of old cars unfit for service, but which are carried on the books of the several companies from year to year or until such time as opportunity presents to dispose of them.

In the city of Utica, N. Y., this fact is clearly demonstrated.

The total number of cars in operation is about 32, whereas the total number reported is 67, showing that the larger portion was surplus cars.

It is personally known to the authors that this surplus was made up of old cars, a number of which were sold for $25.00 each, which fact shows the unfit condition of these cars for service.

This condition of affairs of surplus old cars is in some degree general with all street railway companies.

This tabulation is based on census of 1890 as to population; the other statistics are for the year 1891.

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PART VI

ESOLUTIONS FROM MILWAUKEE COMMON COUNCIL PROCEEDINGS ON VIOLATION OF EARLY ELECTRIC STREET RAILWAY ORDINANCES.

(April 11, June 16 and December 15, 1890.)

(Extract from Common Council proceedings 1889-1890, found on page }, under date of April 11, 1890.)

COMMUNICATIONS FROM CITY OFFICERS

The chair presented the following:

OFFICE OF THE BOARD OF PUBLIC WORKS

Milwaukee, April 11, 1890.

) the Honorable the Common Council.

Gentlemen: We herewith report that the West Side Street Rail- ıy Company is operating its road by electric power in violation of e terms of an ordinance passed October 14, 1889, granting to said mpany an electric-power franchise.

Section 4 of said ordinance provides, among other things, that all ɔrk authorized by said ordinance shall be done to the satisfaction the board of public works of the city of Milwaukee.

Inasmuch as the main electric-wire conductors are not placed or nstructed at such an elevation above the surface of the streets as is quired by said ordinance, that is to say, "not less than 18 feet above e surface of the street," the said work is not satisfactory to this ard.

On April 3, we caused a notice to be served upon the said rail- ıy company objecting to the operation of its railway and ordering e said company to comply with the ordinance, but they seem to dis- gard said order.

We respectfully refer the matter to you for such further action as you may deem expedient.

C. P. FOOTE,
W. P. O'CONNOR,
GEO. P. TRAEUMER,

Commissioners of Public Works.

Referred to the Committee on Railroads.

(Extract from proceedings of the Common Council 1890-1891, found on page 179, under date of June 16, 1890.)

OFFICE OF THE BOARD OF PUBLIC WORKS

Milwaukee, June 16, 1890.

To the Honorable the Common Council.

Gentlemen: On April 11, 1890, we reported to your honorable body that the West Side Street Railway Company had not constructed its electric-wire conductors in accordance with its franchise ordinance, the wires not having been strung to the required height, but no action has, as yet, been taken in the matter.

Since that time the wires have been constantly "sagging" and settling until now they are dangerous to life and property. New strong poles were put up on Wisconsin Street, but they are not in service, the old poles still carrying the wires.

We respectfully recommend that immediate action be taken in this matter to protect the public, and offer the accompanying resolution.

W. P. O'CONNOR,
G. H. BENZENBERG,
GARRETT DUNCK,

Commissioners of Public Works.

Resolved, That the city attorney be and is hereby directed to institute such proceedings against the West Side Street Railway Company as will become necessary to compel the said company to "string" or place its electric wire conductors to the proper height required by the provisions of a certain ordinance passed October 14, 1889, granting to the said company permission to erect said wires, the said wireɔnductors, as now placed, being a menace to the safety of the public.

Referred to the Committee on Railroads.

(Extract from Common Council proceedings 1890-1891, found on page 533, ıder date of December 29, 1890.)

Ald. Dewerth presented the following:

Milwaukee, Dec. 15, 1890.

o the Honorable the Common Council.

Gentlemen: The Committee on Railroads recommend that the ıllowing old matters be placed on file, viz.:

A communication and resolution relating to electric wires of ʹest Side Street Railway Company.

A communication reporting violation of ordinance by West Side ailway Company.

PART VII.

EARLY ELECTROLYTIC CONDITIONS THROUGHOUT UNITED STATES CANADA AND EUROPE

There are many good and substantial reasons why the compiler has reproduced the following references, and which the interested reader can gather much valuable data from for the purpose of following the subject-matter from its beginning to the present day (1920). The compiler distinctly recalls the time when the subject of "Electrolysis" was first discovered, and he became actively interested in the problem following but two years after the appearance of this ramified evil of Electrolytic Deterioration, and has followed the subject extensively ever since. This is a privilege, covering over 27 years of study, which possibly no other living engineer today has been permitted to enjoy so extensively.

E. E. BROWNELL,

Consulting Electrical Engineer.

Philadelphia, Penna., May 1, 1920.

PITTSBURGH, PENNSYLVANIA

(The Electrical Engineer, December 31, 1890, Page 728)

DETERIORATION OF ELECTRIC RAILWAY RETURN CIRCUITS

President D. F. Henry of the Federal Street and Pleasant Valley Railway Company, Pittsburgh, Pennsylvania, has been complaining of the rapid deterioration of the return conductors of that road. He says that they may have to adopt an overhead return conductor, owing to the rapid deterioration of the underground connecting wires in the peculiar soil of Pittsburgh. A striking fact is noted in connection with the return conductor leading from the track rail to the negative poles of the generators. This is a large insulated wire, and that portion which is laid under the floor of the powerhouse is encased in a wooden box or trough, while under the sidewalk about six feet from the rail it is embedded in the soil. On cutting through the insulation recently that portion of the conductor laid in the soil was found to be almost destroyed, while the section in the wooden casing was, apparently, as good as new.

PROVIDENCE, RHODE ISLAND

(The Engineering Record, May 14, 1892, Page 396)

A STREET RAILWAY FRANCHISE LAW

The amended provisions of the franchise under which the street railways in Providence, Rhode Island, will be operated, if the measure which has passed one branch of the Legislature becomes a law, contain some points of interest to other communities. The present company has for years enjoyed a monopoly, and a readjustment of the relations of this corporation, and the gas and electric lighting companies to the city has been for some time contemplated. Having substituted electric for animal traction upon one line, it was desired to equip all the routes, over fifty miles, with electric power. It was found that the loan to cover the cost of the proposed improvement could not be placed, because the company's grant included the city's right to order the removal of rails after ninety days' notice. The measure now on its passage is a compromise between the parties in interest. It gives the company a twenty-years' franchise for a payment of not less than three nor more than five per cent of the gross earnings, the rate of payment to be adjusted every five years. The law reserves to the city the right to order the substitution of any other method of street-car propulsion which may be perfected so as to be of equal practical or commercial value to the trolley system, also the right to order the construction of new lines whenever, in the opinion of the City Council, the public good shall require them. One year's time is given the company to obey either of these orders. The railway company is required to keep in repair that part of the street or highway occupied by its lines, and also to transport by its own power, from the terminus of its lines into the city, cars of any other street railroad line in consideration of a reasonable compensation. The original clause regarding the removal of the rails is amended to require the city to grant a right as nearly similar in public convenience as possible in another street.

ENGLAND

TROUBLE ON ELECTRIC SUPPLY MAINS

(The Electrical World, June 4, 1892, Vol. XIX, No. 23, Page 390)

A couple of explosions in September last and several more recent instances of damage to gas and water connections, due to defects on the St. James and Pall Mall Company's system of mains, have afforded the gas journals a splendid opportunity of indulging in alarmist talk with at least a small show of reason. The facts are briefly as follows: Owing to accumulations of gas and water and some sparking from a faulty pilot wire, there were two explosions last autumn. In March this year a pastry cook in Piccadilly had a lead water pipe eaten through twice, and several of his assistants received shocks from tals; and a few days after this the back of a gas meter resting against a damp wall in an adjacent house was found to have been pitted, apparently by electrolytic action. These occurrences soon brought Major Cardrew, the Board of Trade Inspector, upon the scene, and he not unnaturally had his suspicions about a 2,500 volt main belonging to the London Electric Supply Corporation, which terminated in a "dead end" close by. This main was, however, found to be above suspicion, and the fons et origo malorum was ultimately discovered in the iron culvert of the St. James' Company, between which and the gas and water pipes there existed a difference of potential of six (6) volts. On opening the culvert the negative conductor was found to be in contact with the iron through some fused lead-covered pilot wires lying at the bottom of the trough. On putting matters right at this point a near-by dead "earth," which had troubled the St. James company since the autumn and which they had been unable to localize, disappeared. Major Cardrew has reported in favor of the immediate removal of all the pilot wires from the interior of the conduits, and is of opinion that "the steps to be taken by the Board of Trade to provide against the recurrence of similar faults and their consequences will require mature consideration."

EFFECTS OF RAILWAY CURRENTS ON FIRE ALARM CIRCUITS

By Chas. C. Drake

(The Electrical World, Vol. XX, No. 6, Aug. 6, 1892, Page 84)

In reading your editorial in your issue of July 30, in reference to electricity the supposed mischief-maker again, I would like to state that since the electric street car road was started, we have had considerable trouble with our police telegraph circuits which are grounded. When this road was first started, in less than four days a new 10-cell Callaud battery failed on one circuit. After trying to locate the trouble by reversing the ground, I overcame it. In about three weeks the street car company reversed the polarity to ground, unbeknown to me, and in about three and a half or four days my battery failed again. After reversing the grounds and building up the battery again, all went well. But I find that my batteries do not work as well, and will not last more than half as long. I have had to double them, where I only used 48 before I now use 96, and they are not as satisfactory as before.

I reported these facts to our board of commons and recommend that they make our circuit metallic.

SAGINAW, MICHIGAN

(The Electrical World, July 30, 1892, Page 68)

SUPPOSED ACTION OF GROUNDED RAILWAY CURREN ON LEAD WATER PIPES

In a number of Western cities it was noticed lately that sor lead water pipes laid in the ground were breaking down faster th they ought to, thereby causing considerable trouble. In one case the City of Saginaw, Michigan, the lead pipe which was giving tro ble was taken up and found to be badly corroded. A portion of th pipe is shown in the accompanying cut (facing page 102 of this r port), which is a full-size reproduction of the original piece sent u It will be noticed from this that the corroding action appears to hav been chemical in its nature, and that it seems to have been quit powerful and irregular, penetrating deeply in some places and not a all in others. In places where there had been no action the pipe, as it reached us, was partially covered with some black substance resembling black varnish, which had evidently protected the lead under it from the corroding action. The compound into which the lead had been changed had all been washed off on the fragment sent us, and we therefore could not make any examination of its nature.

An investigation was made to ascertain the cause of the trouble and at first it seemed impossible to trace it. A chemist analyzed the soil and made other chemical tests. He found the soil was of the usual nature, with the exception that it contained chlorides of magnesium and calcium, but said that he could not find anything in the soil that would in any way cause the lead pipe to show the pitted appearance as seen on this fragment.

It was finally suggested by some one that as this lead pipe ran parallel with the street railway, the corrosion may have been due to the "sparks that flash from the rail through the earth to the lead pipe." Without endorsing this statement as it is given, it appears likely from the scant information at hand that there is some truth in the belief that the earth return currents were the cause, though no definite statement to this effect can be made without having further data as to the conditions.

The appearance of the corroded spots is not as if the lead had been burned out, but is precisely like a certain corrosion which takes place on lead storage battery plates under certain abnormal conditions. It is, therefore, probably chemical in its nature, caused by the electrolytic action of the ground return currents from the railway, stimulated by the presence of certain mineral salts in the soil. Additional data, however, is necessary before the cause can be definitely attributed to these currents. We allude further to this in our editorial columns.

ELECTRICITY THE SUPPOSED MISCHIEF-MAKER AGAIN

(The Electrical World, July 30, 1892, Vol. XX, No. 5, Page 67)

Another case has been brought to our notice in which serious mischief was done by some unknown mysterious intruder and as electric sparks were seen near the places where the damage was done, electricity was, of course, credited as the cause. It is not unlikely, however, that this time, as a great exception, the man who is always ready to attribute any mischief to electricity has, by sheer chance, been correct in his prophecy. This was not surprising, for, according to the law of probabilities, if all danger done, no matter what it is, is on general principles always attributed to electricity (which we admit is among the long list of mischief-makers), then sometimes the guess must turn out to be correct, but the guesser in that case does not necessarily deserve any credit unless by chance he really did know what he was talking about. The case was as follows: In a certain place, underground lead pipes used for water service were found to break down frequently without any apparent cause; on examining the pipe, of which we show a view in another column, it was found to be very badly corroded, looking almost as if the rats had nawed it. The soil was analyzed by a chemist, but no direct cause uld be found in the constituents of the earth; as the pipe ran parallel to the electric railway, it was concluded that electricity did it. Before admitting definitely that it did, it would be necessary to have further details than those which we have received. But let us assume that the following was the cause, all of which appears likely from the facts received; that the pipe ran parallel to the electric railway; that a ground return was used; that chlorides of magnesium and calcium were contained in the soil; perhaps, also, that the bonding of the track was inadequate, or perhaps very imperfect. These conditions are sufficient to cause a shunted current to pass through a neighboring parallel-running lead pipe, which is by far a better conductor than the soil itself, unless the latter is very moist, as the current must pass from the ground to the lead (or vice versa) and as most ground conducts by virtue of its moisture, there should be according to the well-known laws, electrolytic action on the outside of the pipe. This action might be greater with a positive than a negative current, but under certain conditions even a negative current will corrode lead instead of cleaning it as usual. It therefore is not essential that the ground current be positive. Nor is it essential that the lead pipe runs parallel to the track, for it might have run so as to act as a shunt to a loop, in which case the action would have been all the greater. It is claimed by some that the earth return current does not necessarily flow through the ground back to the source, but that it is diffused, as it were, in the ground; even admitting this, the lead pipe would be likely to act as a diffuser or equalizer, as it is well known that the ground itself is not the best kind of conductor unless very moist, while lead pipe, owing to the intricate metallic network with which it is connected, as well as to the water circulating through it, would act as an excellent diffuser. Railway currents are often very great in quantity and a comparatively small portion shunted off into a lead pipe might in time do much mischief electrolytically. Chlorine is one of the worst elements to have in a lead storage battery as it makes what in common parlance is termed "a bad white mess" of both the plates. As its presence in the soil was shown by the chemist, it is not unlikely that it shares the blame, especially as it would require but a comparatively small current to produce very decided effects on the lead pipe. It is also likely that this action would be concentrated where the salts are most abundant, and may possibly not exist at all, when such salts are not present. A further investigation intelligently made by unbiased parties might give results which are very instructive, besides being interesting. If the cause is really attributable to the grounded current, it is simply another case which shows the numerous snags into which one runs by using the earth as part of a circuit. It would also be a more serious objection to grounded railway circuits than their effect on the telephone lines, which can readily be avoided by using metallic circuits for the latter. Water pipes cannot well be insulated or protected electrically in any other way. Our object in mentioning this case is, that if electricity is really the cause, the sooner it is definitely known the better, in order that some provision be made to avoid repetition, as the general destruction of water pipes in a city would be a very serious matter. Trolley roads are already blamed for enough mischief, and it is therefore the wisest policy in the end to find out definitely whether this is a valid cause for complaint or not, and if so, to find the remedy and then to apply it conscientiously. Even though it may cost something it will doubtless be the best in the end. The ears of the opponents of the trolley system are wide open, taking in all such rumors. According to the old saying, "in times of peace prepare for war." The question ought to be definitely settled as soon as possible, and if these complaints should be well founded a remedy ought to be found.

THE CORROSION OF LEAD SERVICE PIPES

By Ernest Speidel

(The Electrical World, August 6, 1892, Vol. XX, No. 7, Page 98)

I read with considerable interest the article and editorial on the corrosion of lead service pipe in The Electrical World of the 30th ult.

Since I was "the chemist" who did "the guessing" I want to call attention to the fact that, as far as my investigation was concerned, there was no guesswork about it. My report to the Water Board was short and to the point, free from the technical points interesting to the chemist and to the electrician. I took up the different points in my line of work and carried them to the end, finding always that chemical action alone did not do the harm, but that electricity in some form was the mischief-maker. Knowing the proximity of the lead pipe to the track of the electric street railway, I consulted expert electricians as to how it was possible for the electric current to reach the pipe, and from them got their opinion; thus being doubly certain of my theory I made my report.

The chlorides spoken of were in the soil only in minute quantities and could in no way have acted on the lead of the pipe. The electrolytic action decomposed the lead, forming an oxide of lead, which in turn combined with the chlorine that was liberated from the chlorides by the same electrical action. Had no chlorides been present, simple lead oxide only would have been formed. The corroded spots spoken of in The Electrical World all contain chloride of lead at one time.

SAGINAW, MICHIGAN

(Engineering News, September 22, 1892, Page 273)

CORROSION OF LEAD PIPES BY ELECTRIC CURRENTS

Some puzzling cases of lead pipe corrosion have recently been traced to the action of electric currents setting up an electrolytic action upon the pipe. In one case in the City of Saginaw, Michigan, a lead pipe ran for some distance parallel to an electric railway and when taken up was found to be corroded completely away in spots, its appearance being very similar to that of a lead plate in a storage battery. An examination of the soil showed that it contained chlorides of magnesium and calcium, and it is known that chlorine is very destructive to lead battery plates. The "Electrical World" in a recent careful review of the case reached the conclusion that while the case of the corrosion was not absolutely proved to be the electric current, the evidence pointed sharply in that direction. If a ground return was used, a shunt current would naturally pass through a neighboring parallel running lead water pipe, since it would be a far better conductor than the ground itself, unless the latter were very moist. As the current must pass from the ground to the pipe or vice versa, electrolytic action must take place on the outside of the pipe. It is not even essential that the pipe should run parallel to the track, for it might have run so as to act as a shunt to a loop, in which case the action would have been all the greater.

ATHENS, GREECE

Another somewhat similar case of pipe corrosion is reported at Athens, Greece, in the "Electrotechnische Zeitschrift." The neutral wire of the central station at Athens was grounded by attaching it to a lead pipe about a mile long and two inches in diameter. The lead covered cables at Athens are placed in wooden troughs coated with tar and rosin and trouble was first experienced in the giving away of the lead covering of one of these cables, which showed a series of small pin holes resulting from a slow chemical disintegration of the lead sheathing.

Soon other accidents followed. Now there was a positive con-

ctor at fault, now a negative one, and these troubles caused th
mpany to employ greater care in the insulation of the entire ir
llation. One thing became evident, that the grounding of th
utral wire had largely increased the chances of danger to the pipe
m burning through, for it was found that strongly insulated con-
ctors soon became faulty, and at last useless.

A short time ago the company was notified that a water pipe
d become leaky. A careful investigation revealed the fact that the
tire pipe showed a series of small holes, in fact, exactly the same
ns of chemical disintegration were noticed which had been ob-
ved in examining the burned cable.

The walk on which the pipe is laid is at several points covered
water, continually flowing into the channel, and this water con-
ns a small amount of oxygen. At these points the pipe was intact,
t wherever it touched the damp masonry of the walk without be-
flooded by the running water, the pipe was perforated. At the
ints where the pipe touched the masonry the metal was badly
idized and crumbled at the mere touch, and the chemical disin-
ration at the soldered points was especially noticeable.

It was first doubted that the trouble had been caused by elec-
ytic action, but when it was found that other lead pipes which
e not attached to electrical conductors, but which had been placed
he same channel, showed no trace of damage, it was pretty well
en that the disintegration of the metal had been caused by the
rical current. The fact that the pipe was badly damaged at the
s to which the conductors had been soldered, while wherever
ipe was surrounded by flowing water scarcely any damage could
tected, was another argument in favor of this view.

s a result of this experience the managers of the Athens Com-
have concluded that grounding the neutral wire in three-wire
s is not to be recommended. It is argued in its favor that it
the use of an uninsulated conductor for the neutral wire and
es danger from short circuits. The managers believe, how-
at it would be dangerous to build an entire system of an un-
d neutral wire, and that the danger from short circuits is in-
rather than decreased by grounding the neutral.

LECTROLYSIS AND LEAD WATER PIPES

Electrical World, Oct. 1, 1892, Vol. XX, No. 14, Page 205)

recent number of "The Electrical World" attention was called to what was supposed to be a case of damage to lead water pipes by the electrolytic action of a street railway current. This case, it will be remembered, was in the city of Saginaw, Mich., where a lead pipe ran for some distance parallel to the electric railway. On taking up the pipe, it was found to be seriously corroded at numerous points, its appearance being similar to that of a wornout storage battery plate. Since the presentation of this case in our columns, our attention has been called to a very similar occurrence in the city of Athens, Greece. Mr. Etienne de Fodor, the manager of the Athens central station, informs us that the neutral wire of one of their circuits was grounded by connecting to a lead pipe nearly a mile in length and two inches in diameter. Trouble was experienced by the failure of one of the lead-covered cables, which showed a series of small pin holes apparently resulting from the gradual disintegration of the lead sheathing. This failure occurred upon both the positive and negative mains of the three-wire system. It was soon discovered that the water pipe to which the neutral was grounded was leaky, and an examination showed that the entire pipe was filled with a series of small holes similar to those found in the sheathing of the lead-covered cables. At several points the water pipe was in contact with flowing water, and at these points it was found to be uninjured, but wherever it touched damp masonry and was not in contact with running water the perforations mentioned above were found, the metal at these points being badly oxidized and crumbling at the mere touch. Chemical disintegration was especially noticeable at the soldered joints of the water pipe. Investigation showed that other lead pipes placed in the same channel, but not connected to the return circuit of the electrical conductors, exhibited no trace of injury, and this, together with the fact that the pipe was badly damaged at the point to which the conductors had been soldered, was taken to indicate that the disintegration of the metal had been caused by the electrical current. Another point which seemed to strengthen this view was the fact that wherever the pipe was surrounded by flowing water scarcely any damage could be detected, and this was attributed to the presence of a small amount of oxygen in the flowing water. The result of this experience in the Athens central station has been to lead the company to believe that the grounding of the neutral wire in three-wire systems is not to be recommended. The managers believe that an entire system constructed in this way would tend to increase the danger from short circuits rather than decrease it. If any of our readers have had similar experiences of this kind we should be glad to have them brought to our attention. So far as we are aware, the case noted at Saginaw, Mich., and this one at Athens are the only experiences of this kind that have ever received public attention.

NOTES

(The Engineering Record, Vol. No. 3, June 15, 1895, Page 38)

Inspection for Electrolysis, Saginaw, Mich.—According to the annual report of the Board of Water Commissioners of Saginaw, Mich., considerable trouble has been experienced during the year from electrolysis. Examinations at various places showed that although the destruction of pipes was greatest near the powerhouse, yet corrosion to a serious extent has taken place at remote points. A brick conduit has been constructed across one of the streets in which a service pipe has been laid in such a manner that it can be examined from time to time to observe whether the more systematic bonding of the rails will be effective in preventing the trouble.

SHOULD THE POSITIVE OR NEGATIVE POLE OF A GENERATOR BE GROUNDED?

(The Street Railway Journal, December, 1892, Page 741)

The question always arises in connecting the generators in an electric railway station, whether the line should be made the positive or the negative side of the circuit, and, as our readers know, practice has varied widely in this regard. To obtain a decision on this point the Street Railway Journal requested the opinion of a number of prominent electrical engineers upon the subject. Their replies are given below:

Mr. Elihu Thomson, of Lynn, Massachusetts, says: "Yours of the 11th inst. has been received. In answer to your inquiry I would say that I do not think there is any method of connecting up generators which is general for all cases. My opinion is that it would be the best practice to alternate the connections from time to time."

Mr. Frank J. Sprague, of New York, says: "In reply to your favor of November 17, I think the better plan is to make the line the negative side of the circuit, so that if there is any arcing at joints or supports the trolley wheel will be the sufferer instead of the line, and also because the earth plates, where used, will last longer."

Mr. S. H. Short, of the Short Electric Railway Co., Cleveland, Ohio, says: "I think it best to have the negative pole of the dynamo connected with the trolley line, this method of connection causing less trouble with electrolysis in ground wire and rails."

Mr. J. H. Bickford, of Salem, Mass., says: "I hardly feel like expressing myself upon the question named. There is a great difference of opinion in regard to this matter, and there are, undoubtedly, arguments in favor of both ways. My preference in the matter would be to have the overhead wire positive, although as a matter of protection to the trolley wire itself from becoming burned when a break occurs between it and the trolley wheel, it would be better to have it negative, as the damage would then occur to the trolley wheel. In a town where there are several lines of road operated by different companies, it is, of course, absolutely important that all the overhead wires should be of the same polarity, and as a general thing the trolley wire is positive. There may be some other good reasons, aside from those I have mentioned, for making the trolley wire negative, but I have never given the matter sufficient consideration to determine what they are."

Mr. J. H. Vail of the General Electric Co., New York, says: "I believe it is for the best interests of the operating company, that the ground connection should be the positive side of the system. As the current travels in the direction from positive to negative, the results of arcing between the trolley and the trolley wire will not be as liable to impair the durability of the trolley wire as if the direction of current were reversed. For instance, under the latter condition, and an arc taking place, the trolley wire might be seriously reduced in strength by burning at the arc between wire and trolley wheel, the fused metal being carried from the wire to the trolley wheel. But with the trolley wire as a negative side, under an arc, the trolley wheel is more liable to lose its metal. I believe that examination of burned trolley wheels proves this.

"In addition to the above, I have frequently received reports as to the result of damages from lightning. It has been specially observed by several outside men in charge of construction and operation of railway plants, that the effects from lightning are less disastrous when the positive side of the system is grounded, than when the negative side is. I believe that a standard of practice should be agreed upon by all parties interested in constructing and operating street railway systems by electricity, and that the standard should be universally followed.

"Some constructors practice certain methods of bonding and grounding street railway tracks, the work lacking both permanency and efficiency, as well as being under certain conditions detrimental to other systems of distribution for public service. On these practices it is not necessary for me to enlarge at this time. It appears to me as being of vital importance that faulty methods of work should be entirely eliminated and that the best methods of construction, embracing permanency and efficiency, should always be followed."

THE GROUND RETURN

(The Electrical World, Dec. 3, 1892, Page 357)

In the course of the discussion at the recent meeting of the American Street Railway Association at Cleveland, Ohio, Mr. F. S. Pearson, chief of the steam and electrical department of the West End Street Railway Company of Boston, Mass., brought up some points in reference to the ground return which, from his long experience in this line, should prove of interest to practical men.

In small towns and systems where there are few cars running, Mr. Pearson thinks the ordinary method of returning the current through the rails and supplementary wire is sufficient unless the distance is great. On large roads where the traffic is heavy, more return grounds than have been used heretofore will have to be installed. It was found in Boston, Mass., and from lack of return feeders a great deal of electrolytic action was caused in the supplementary wires, and the West End Company is now putting up a large amount of overhead copper for return grounds, since the underground will corrode and rust away. There is no advantage in using iron, as the conductivity is only one-seventh that of copper. Originally the positive current was run through the trolley wire, but it was found that the action on the supplementary wires was too great, and so the negative was put to the trolley wire. It was not thought that there would be much less effect, as it merely transfers the action to another point.

In reference to water pipes Mr. Pearson said that he did not have in mind any particular trouble with water pipes, but naturally, if there is a large volume of current going through the earth, it will take hold of a water pipe or a gas pipe, or any other pipe, and there will be an electrolytic action: and in any large railway system, if the attempt is made to use the earth for return ground by putting in ground plates in driven wells, or by putting them in the rivers, and the return current is not provided with a good metallic circuit, the current must inevitably injure the water pipes and all other pipes. The current, when it leaves the car, goes into the ground, and, taking a water pipe, may go a mile on that pipe, then leave it for a better conductor, the result being that the pipe will be corroded at this latter point.

As to using old rails for a return the difficulty is to make a good joint. If the rails could be welded or soldered this plan might work, but the joints could hardly be made in any other way so that they would carry the large volume of current without heating or corrosion. To joint the rails by copper plates would be a poor construction, as the iron and copper would form an electrolytic element and cause corrosion, even if no current was passed through the joint. The passage of the current would also heat the joint and cause further oxidation.

In the early days of electric railroading an attempt was made to use the rail for a return current and not put in supplementary wires, but it was found almost impossible to maintain a joint of any sort. When a large volume of current is sent through the joint oxidation takes place, and the joint soon becomes worthless. This condition will exist no matter how large the joint is made, and if dissimilar materials or metals are used a local electrolytic action will also take place. With steel in contact with iron the effect will be produced in a lesser degree than with copper, and it will take longer for the trouble to develop.

Old steel and iron cables had been used in the cross of rivers and for connecting the supplementary wires from one side of the track to the other, but the objection to the cable is that it cuts away very fast. For instance, in one place seven ropes or cables had been put in and soldered thoroughly at each end, and in less than four months they were entirely gone. If the soil was comparatively dry and sandy this scheme might do for a while, but where it is moist and solid it is a question whether the cables will last long enough to pay for putting them down. As a rule in track construction today the West End road uses supplementary wires as well as bond wires on the rails, the former having a low resistance as compared with the bond wires and joints. The greater current passes on the supplementary wire and does not go through the joint. If the supplementary wire is cut and all the current is made to pass through the bond wire there is no trouble, but as long as a good supplementary conductor is maintained the current will not pass through the bonded wire, the joints will remain cool and there will be no great tendency to oxidation, especially if tinned rivets are used.

WASHINGTON, DISTRICT OF COLUMBIA

(Engineering News, December 20, 1892, Page 615)

The latest case of water pipe corrosion caused by electric curents is reported from Washington, D. C. Lieut. J. O. Manson, of 07 New York Ave., has reported to Engineer Commissioner Rossell hat the galvanized iron service pipe on his premises corrodes, and ecomes miserable in a short time. An investigation is to be made.

THE SINGLE TROLLEY vs. TELEPHONE ABROAD

(The Electrical World, February 11, 1893, Vol. XXI, No. 6, Page 9)

Our cable dispatch from London this week brings tidings of the rst decision in the English courts of the question which so long gitated the electrical street railway and telephone interests in this ountry. It was the same old question as to whether the single troly had a right to exist in the neighborhood of already existing telehone lines. As we understand it, our English cousins have fought out on the same old lines with which we are so familiar and the ecision followed closely on the precedents established here. It is ther a reversal of the usual order of things for America to establish recedents for the mother country, but as the precocious child not frequently outstrips the parent in these days, it is not surprising at Young America should outstrip the old lady in things electrical. he fact that American rulings were frequently referred to is a comiment that our bar will appreciate, as much as will electricians the nplied admission of our advanced position in the application of ectricity.

UNDERGROUND WIRING FOR ELECTRIC RAILWAYS

(Municipal Engineering, 1893, Volumes 4 and 5, Pages 28, 29 and 30)

In a discussion on underground wiring for electric railways, at e Cleveland meeting of the American Street Railway Association, r. Pearson, of Boston, said, that while the ordinary method of reurning the current through the rails and supplementary wire would e sufficient in small towns or where there are few cars running, on rge roads where the traffic is heavy, more return grounds than ave been used heretofore will have to be installed. It was found n Boston that from lack of return feeders there was a great deal of lectrolytic action on the supplementary wires, and as a remedy a large amount of overhead copper is being put up for returns. It was not thought advisable to put it underground on account of the rapid corrosion, and there is no advantage in using iron on account of the low conductivity. In regard to using the trolley wire as a positive or a negative, he originally ran the positive current through the trolley wire, but found that the action on the supplementary wire was too great, and changed it and put the negative to the trolley wire. This merely transferred the action to another point.

In answer to a question regarding the trouble with water pipes, Mr. Pearson said that he did not remember any particular trouble with water pipes, but if there is a large current passing through the earth it will take hold of any convenient pipe, and there will be electrolytic action. In any large railroad system, if the attempt is made to use the earth for return ground by putting in ground plates in driven wells, or elsewhere, and a good metallic circuit is not provided for the return current, the current must inevitably injure the water pipes and all other pipes. The current when it leaves the cars goes into the ground, and taking a water pipe may go a mile on that pipe and then leave it for a better conductor; the result being that the pipe will be corroded at this latter point.

Mr. Richardson, of Brooklyn, asked in regard to using old rails as returns by putting them in the ground, using five or six or more, side by side and so making a continuous path for the return circuit, proper fastenings being provided.

Mr. Pearson thought it would be difficult to make a good joint, and that without it there would be heating and corrosion, and that a copper joint would not do as there would be electrolytic action under any circumstances. It was attempted in the early days of electric railroads to use the rail for the return conductor without putting in supplementary wires, and found almost impossible to maintain a joint of any sort. When a large current is passed through a joint oxidation takes place, and the joint soon becomes worthless. This condition will exist no matter how large the joint is made, and if dissimilar metals are used a local electrolytic action will also take place.

In answer to another question Mr. Pearson said that they had used a considerable quantity of old steel and iron cable, in getting across rivers and connecting supplementary wires, but that it cut away very rapidly. For instance, in one place seven cables were put in with thoroughly soldered joints, and in less than four months they were entirely gone.

Mr. F. S. Holmes said that he had the opinion of an engineer experienced in street railroad work, to the effect that when there was a sufficient number of ground plates along the line the current was about equally divided between the rail return and the ground wire. The construction we have today, where ground plates are used for return currents, makes the trolley wire and the various plates and supplementary wire along the line of the road positive and the large ground plate at the station negative. This is wrong, because the supplementary wire and ground plates along the line are rapidly corroded, while the negative plate at the station is uninjured. The conditions should be reversed, the station plate being made positive and the line plates and supplementary wire and trolley negative to it. Corrosion will then be largely confined to the station plate, which can be easily replaced. To accomplish this the current must, of course, flow out by the ground, which will be positive, and back by the trolley wire, which will be negative.

MILWAUKEE, WISCONSIN

(Extract from Milwaukee Sentinel, Sunday, April 30, 1893)

A WATER MAIN BURSTS

West Side Electric Street Cars Have to be Abandoned

UPPER WELLS STREET QUICKLY FLOODED

The Water Pipe Is Supposed to Have Been Eaten Away by Electricity, and the Accident Comes so Suddenly That for a While Great Consternation Is Created—Horse Cars Will Have to Be Used Today—Steps to Repair the Damage Immediately.

Shortly before 8 o'clock last night the water main in front of the West Side Railway powerhouse on Wells Street burst and the street was quickly filled with water. It was impossible to run the electric cars over the track at that point as the tracks were completely submerged in a very few minutes. The cars continued to run on the State and Twelfth Street lines until about 9 o'clock. At that time the whole line had to be abandoned. Every effort was made to get all of the electric cars near the powerhouse and they were run into the barns. The fires had to be drawn from the boilers, as the break in the main made it impossible to get any water for getting up steam.

The break occurred after everyone had left the water office and no one could be found to turn off the water. It was nearly ten o'clock when C. J. Trapashuh of the water department arrived on the scene. All the water along Wells Street from Fourth to Twelfth Street was shut off and will remain so until about 4 o'clock p. m. today, by which time it is expected that repairs will have been made. Mr. Trapashuh said: "The break was caused by the eating of the pipe by electricity, which comes from the main car cables. This cable runs parallel to the pipes at this point and close to it. These same accidents have occurred in front of powerhouses in other cities where the main cable is close to the water main and I have been expecting this to happen here for the past six months. The lead pipe connecting with the water main and running to the property directly opposite to the powerhouse has been eaten away three times within the past two years."

The water main is six feet below the surface at this point and the blocks in the street have been displaced by the force of the water for a considerable distance. The street car company would have had to leave its cars scattered along the line last night had it not been for a supply of water which is kept in a tank in case of emergency. After the electric cars were all in several horse cars were sent out. This was after ten o'clock. The late patrons of the line, who came down in the electric cars, were surprised at having to go home in the old-time "bobtails." The line will, it is promised, be in operation today. A line of hose will be borrowed from the water and fire departments and water will be had from the fire plug at the corner of Wells and Twelfth Streets. A force of men will begin the work of repairing the break early this morning.

BOSTON, MASSACHUSETTS, AND INDIANAPOLIS, INDIANA. THE ELECTROLYSIS OF GAS PIPES

(The Engineering Record, April 29, 1893, Page 439)

The effect of electric currents on gas and water pipe is attracting attention in Europe as well as in America. In our issues of March 18 and April 8 were described some phenomena noted at Boston, Massachusetts, and Indianapolis, Indiana, in connection with the gas pipes of those cities, and we give below an abstract of a paper by M. P. Jousselin on the same subject, as it has been developed in Paris, France. The abstract is taken from a full translation of the paper which appeared in the Western Electrician under the title of "Dangers from Gas in Electrically Lighted Cities":

Perforations of gas pipes by electrolysis have been extremely frequent in the last few years; they have numbered by the hundreds.

and are produced most frequently in lead pipes, though they are met with in the cast-iron pipes. As the leaks occur upon the public streets, the employees of the gas company hasten to the spot and investigate. When the pipes were uncovered holes are at once noted on their surface, through which the gas is escaping. The gas system of Paris, France, under the sidewalks is covered with earth of a calcareous character or with plaster coming from buildings that have been torn down, and, therefore, contains carbonates or sulphates of lime. A workman looking for leaks while digging with a pick frequently notices that the ground liberates a certain amount of heat, and that the service pipe is affected electrically even up to the meter. At the instant that a loss of electricity occurs in the cable carried under the sidewalk, the current takes the path of the gas system in the vicinity. The carbonates or sulphates of lime, as the case may be, are decomposed by reason of a considerable rise of temperature, and carbonic acid or sulphuric acid is carried to the pipes. When this occurs in calcareous earth it is found that the lead at the edges of the holes is covered with carbonate of lead and carbonate of lead hydrate mixed with oxide of lead. The carbonate of lead causes thinning of the metal, and finally produces perforation.

When the ground contains plaster or sulphates of lime, it is noticed that in consequence of the more immediate action of sulphuric acid the perforated hole is cleaner and presents a crater form. The edges are covered with a brownish powder which analysis proves to be sulphate or sulphuret of lead. These effects of sulphuric acid are noted also in the case of cast-iron pipes, even of large diameter, and the periphery of the punctures is covered with a greenish compound which, in accordance with analysis, is ferrous sulphate, ferric sulphate and hydrate of ferric oxide. The reactions which cause the perforations are due to electricity, and are electrolytic phenomena. The action takes place as if in an electrolytic bath, in which one electrode is the gas pipe, the other the cable, and the electrolyte the soil impregnated with water frequently acidulated.

The Edison Company, in whose district most of the trouble has occurred, placed its cables in Doulton's system of flat boxes with a tile cover. This arrangement seemed to possess every advantage, both because it was air-tight and it facilitated inspection. This conduit, built under the sidewalks in earth sufficiently dry and with a slight grade, so that the water leaking in could run off, seemed excellent at first. The cables were kept in a good state of preservation, and no damage to the neighboring gas pipes was noticed. After a time, however, the joints sealed with cement became displaced under the pressure of the ground. The cement cracked and water entered the conduit. There were then many contacts with the earth at the joints, and consequently losses of current ensued, from which gas pipes suffered. The Edison Company did not hesitate to discard the Doulton system in favor of a cement conduit designed by M. Clerc, one of its engineers, and the system has been employed with success on the boulevards. These conduits, which resemble those used by the Electrical Transmission Company, are very small. The work of substitution, which has involved an expense of $80,000.00, is now completed, and today accidents caused by the distributing system are scarcely spoken of.

The gas leaks caused by electrolytic phenomena have caused no appreciable harm up to the present, with one exception, because of the fact that repairs have been speedily made. The exceptional case occurred on the night of June 15, 1892, when there were three explosions in succession in two Edison manholes located in Rue Notre Dame de Lorette, at the corner of Rue Breda; the first occurred at 10:50 p. m. The two manhole covers were thrown into the air, greatly frightening passersby. One woman was thrown to the ground. The covers were replaced about 11:00 o'clock, and half an hour later a second explosion occurred, again throwing the covers into the air. Then at 6:00 o'clock in the morning a third explosion occurred. It was doubtless gas which caused the explosion, for when excavations were made it was seen that the pipes had been punctured in the proximity to the manholes. The gas escaping from the pipes passed through the Edison tile conduits into the manholes, where three different times it formed with the air an explosive mixture.

NASHVILLE, TENNESSEE

(The Engineering Record, July 8, 1893, Page 86)

Electrolysis of water pipe due to street railway currents is reported by Supt. George Reyer, of the Nashville, Tennessee, Water Works. A number of supply pipes on streets occupied by electric railways have become unserviceable on account of pitting due to the pressure of ground currents. No main pipes have yet been injured, but some of those running parallel to car lines are said to be strongly magnetized. Some of the lead services were destroyed in two years, while under ordinary conditions such pipes in Nashville are said to last nearly 50 years.

HAMILTON, ONTARIO, CANADA

(The Engineering Record, July 22, 1893, Page 126)

MBRIDGE, MASSACHUSETTS, INDIANAPOLIS, INDIANA, AND PARIS, FRANCE

William Haskins, City Engineer and Manager of the Water orks, Hamilton, Ontario, Canada, writes:

"We are being much troubled in our Water Works Department the action of electricity on lead service pipes, which eats them ay until they will no longer hold water. In streets where trolley rs are operated we have had to take up and renew several house rvices, and we can not see the end of it. Can any of your numerous ientific correspondents suggest a remedy—such as encasing the e in rubber hose, introducing the water by a small wrought-iron e in short lengths, coated and lined with glass, if such can be ob- ned? Or can you recommend any sort of non-conducting pigment th which the pipe can be coated before the filling in of the trench? y suggestion that will prevent this waste will be very acceptable d thankfully received."

(The effect of the trolley system upon gas and water pipes was t forth in an address by H. A. Allyn, of Cambridge, Massachusetts, fore the New England Association of Gas Engineers, and published abstract in our issue of March 18, 1893; its results in Indianapolis, diana, were noted in our issue of April 8, 1893, and the experience Paris, France, was recorded in the issue of April 29, 1893. Mr. lyn in his paper took the ground that the problem was of too recent igin to allow of the development of a satisfactory remedy. We shall glad to make public the experience of superintendents of water rks who have succeeded in any degree in remedying this trouble, d accordingly refer Mr. Haskins' questions to our readers.)

MILWAUKEE, WISCONSIN

(Engineering News, September 14, 1893, Page 213)

ORROSION OF WATER PIPES BY ELECTRIC GROUND CURRENTS

By Peter Milne

A paper on this subject was read by Mr. Peter Milne, New York ity. In the absence of positive data no opinion was expressed regarding the propriety of permitting ground electric wires to be attached to either gas or water mains, but it was suggested that other means be provided for conducting waste electricity, and it was stated that gas or water mains were never intended for such service. These remarks referred more especially to ground wires of electric systems other than trolley railways. Since the introduction of the trolley, ground currents from this source have done more or less damage to lead and iron service pipes in a number of places, but Mr. Milne had not heard of its having had any deleterious effect upon water mains.

In discussing wire conduits, Mr. Milne suggested the use of vitrified salt-glazed conduits, properly jointed and secured from the frost, in the place of the iron, brass and plank conduits now in use.

This paper lead to some interesting discussion, in the course of which Mr. G. H. Benzenberg, M. Am. Soc. C. E., City Engineer of Milwaukee, Wis., exhibited specimens of iron and lead pipe corroded by electrolytic action, and gave some account of the experience had in Milwaukee. The first street railways using electricity for motive power did not use return wires, but secretly laid wires to the fire hydrants. This was discovered by breaks in main and service pipes due to corrosion, but Mr. Benzenberg thought the corrosion was due not to the passage of the current but to the resistance set up when the current left the pipe at the point nearest the power station in its return to the generators. A temporary compromise with the railway company has been made by which it is allowed to make a good connection with about 50 hydrants and a good connection from the main to the generators, so as to reduce the resistance. It is not expected to entirely obviate the trouble but to reduce it so that it can be successfully coped with, and if the results are not satisfactory the connections will be cut. Where possible to do so it is undoubtedly best to avoid all connections with mains. Mr. Nichols referred to the double trolley system in which a second wire is used by the return current instead of ground wires and rail connections. The discussion showed the importance of the question and a resolution was passed for the appointment of a committee to collect information and report upon the subject.

REPORT OF PROCEEDINGS

OF THE

THIRTEENTH ANNUAL MEETING

OF THE

American Water Works Association

HELD AT THE

PLANKINTON HOUSE

MILWAUKEE, WIS., SEPTEMBER 5–9, 1893

Secretary's Office
95-97 William Street
New York

President: We have another special paper "Electrolysis of Water and Service Pipes," by Mr. Milne. This is a subject of great interest to waterworks men, wherever electricity for lighting or for motive power has been introduced.

Mr. Milne: I fully appreciate the importance of this subject, and as a hydraulic engineer I approach it cautiously. I make no pretensions of electrical knowledge. Indeed, we may say that mechanical electrical energy as at present developed is in the morning of its infancy. What was considered new and novel three years ago in the mechanical application of electrical forces are now obsolete. It ill becomes a man other than a professional electrician to assume a positive position in these matters; indeed one of the most intelligent electricians of the day claims that they are more in the dark, relatively speaking, on the question of electricity, as they approach the grand culmination of the problem, viz., the utilization of all the principles embodied in the science, than most persons would suppose.

Our president had frequent correspondence with me upon this subject, and I sought to obtain a paper at the hands of some of our members; but none seemed willing to undertake it. I have therefore put together a few thoughts on the subjects, which may seem somewhat disconnected, but I trust you will overlook it. An intelligent member of this body said to me: "I do not know anything about electricity." No man in this Association has given more attention to the subject than he.

Mr. Milne then read the paper as follows:

* ELECTROLYSIS

In a general sense this word is compound; it means the decomposition of metals by the action of electricity. It is a word used also to express the action or process of the oxidation of metals by natural law. In galvanic action any metal decomposed by the aid of acids and resolved in suspension, thence deposited upon metal plates or sheets, as in silver plating, copper plating and electrotyping. It is in scientific parlance considered the resultant of electrolysis. Since the introduction of the telegraph and telephone systems of transmission by electricity, electrolysis is the primary element used to furnish the

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*A voluntary paper read by Peter Milne, Hydraulic Engineer, at the thirteenth annual convention of the American Water Works Association, Milwaukee, Wis., Sept. 5, 1893.

energy to produce the power required. The process of electrolysis is either produced by acid batteries or friction dynamos. In each case the decomposition of metallic substance occurs. From these few introductory remarks may be drawn the idea that electricity for the purpose of mechanical application is a power gained at the expense of certain amounts of carbon and oxygen found in all metallic substances, having in their structural and natural characteristics the element of resolving themselves into dynamic energy, by the action of the magnetic current, electricity.

Electrolysis as a principal or agent did not begin to act to the detriment of commercial or financial success until the introduction of electricity for lighting purposes. Experimentally it was found that the potential or power generated at the station, if in excess of what was required for the transmission and light, would decompose, burn up, or destroy the agents of conductivity or else seek its affinity some other way in order to balance the excess of energy generated at the dynamo station. Again, if a positive wire of a powerful dynamo came in contact with a telegraph or telephone wire, mischief ensued by the diversion of the electric current to the telegraph and telephone apparatus, generally the derangement of the switchboards at the stations. This feature of trouble is frequently illustrated in electric storms, of more than ordinary character, in the fact that telephone, telegraph, and electric light wires become agents of natural electricity, and frequently burn up, decompose or oxidize wires and switchboard apparatus.

Coming now to the question of electrolysis of submerged iron, gas and water mains, we will admit the process of electrolysis by natural law as found in the gradual deterioration of metal in the earth under the action of the magnetic elements contained therein, and found in the gas that passes through the gas main, and also found in the water that passes through the water main. Yet with these considerations in view it would appear that in large cities, where many electric wires are used for the transmission of the electric current in telegraph, telephone and other electric service, they are grounded instead of leading the negative or return wires back to the generating station, and in view of this fact the process of oxidation, decomposition, or electrolysis, is not hindered, but accelerated when the current may attack metallic substances. It certainly never was intended that gas and water mains should be used for any such purpose. In the absence of positive data upon the subject I forbear giving any expression concerning the propriety of permitting ground wires to be attached to either water or gas mains—other than to suggest that they provide for conductors of waste electricity in some other way.

THE TROLLEY AND ITS APPURTENANCES

This question is now the absorbing topic among water works engineers and superintendents. It is pretty well known to many of you how the present method of administration of the use of electricity for propelling cars over railways is administered. A brief description may not be inappropriate. First, a central power station equipped with dynamos operated by steam engine or water power, thence the transmission of electrical energy from this station through a cable direct over the railway, or inducted by supplementary cables located on the sides of streets, roads and avenues, thence to a cable or wire directly over the center of the railway. The car is equipped with a trolley, which is simply a wheel running on the under side of the central wire or cable. Through this connection electrical energy is transmitted to a motor located under the floor of the car, and geared to the forward and rear axle of the same. A motor governor, so-called, is attached to the car, and the operator regulates the electrical energy as required.

As long as a trolley wheel is in contact with the overhead wire the electrical current is in action upon the motor, and as determined by the motor governor or brake in a qualified sense, and only in that sense. The stopping of the car does not actually stop the course of the electric current, except under certain conditions. If a high potential prevails, that is, full electrical energy and more than is required for the propulsion of one or more cars, the result of stopping the car is a diversion of the electrical energy hitherto used for its propulsion in the direction of the least resistance to the diverted current. The motor, wheel and rail under these conditions become conductors of the diverted energy, and through these agencies the excess of electrical energy is supposed to finally reach the power station. In some electric railway plants a wire is buried between the rails and connected to them at the intervals where the joints in the rails occur, thus seeking to provide additional facilities for utilizing the return current or unexpected energy and conducting it to the power station.

It is the experience of water works companies in quite a number of places that since the introduction of electric power upon street railways, electrolysis prevails to an extent more or less damaging according to structural conditions, in lead and iron water pipes (known as service pipes). I have not heard or been informed of leleterious effects upon water mains. Since the subject has been ;ht to my notice I have been at pains looking up all information lata I could possibly obtain and have read quite a number of articll speaking of troubles involved. I have as yet to learn of anybeing done by electricians in the way of avoiding the trouble. not believe that electricians are ignoring the question. I do beit is possible and practical, to largely, if not altogether overcome ifficulty. As herein mentioned we know the perishable nature etals buried in the earth and are familiar with Dame Nature's od of reducing by chemical equivalents stored in her laboratory, iings to their original state. It would seem, in view of these and with the experience and knowledge of water works men e their observations, that electricians would cease using iron rass pipe conduits, creosote plank boxes, lined inside and outside, all manner of perishable and expensive ingredients, and resort earthenware conduit, properly glazed and jointed, made sec-l, lengthwise for positive and negative wires insulated, and iso-. I know of nothing that will compare for durability with a vitrialt-glazed conduit, provided it is kept secure from the action of when buried in the earth. I have not heard that electrolysis affect it or that it is an electrode or electrolyte. There is not to nowledge any perceptible elements found in earthenware pipe in any degree contributes their earthy nature to materially aid e production or dissipation of electrical energy. To what extent rinciple of insulation may obtain in earthenware conduit construcis determined only by the skill and care of the mechanic glazing ipe and also equal care in the methods of jointure, in order to e perfect insulation.

Ir. Gardiner: Mr. President, this is a very important matter to water and gas companies; and in some appropriate manner I it would be well for the Association to ask its members to take vation as to the effect of electricity upon water and gas pipes, nulate them, and report at the next meeting; I think it would be able for us to procure all the data possible, not that I apprehend the water or gas companies will suffer in the long run, but the nulation of data will throw the onus on the railroad companies ar the damages. It will be for us to establish the facts and they have to foot the bills. We were in the ground first, and they devise some remedy for this supposed growing evil. I regret Mr. Davis of Indianapolis is not here to state the experience that is gone through. I have seen it recorded in technical journals that Indianapolis particularly has suffered from the damage caused by electrolysis. I think it is well, therefore, for us to solicit from members of the Association during the coming year all the information possible, and full reports for the next meeting.

President: We also have through the kindness of Mr. Davis of Indianapolis, a piece of lead service pipe here which has been affected by electrolysis. You can see the condition it is in.

President displays pipe to the meeting.

In addition to that, I have brought up a few samples from the water mains of this city, and of a service pipe in connection with it. If it is of sufficient interest, I will relate what we have found.

About a year ago complaint was made at my office that a water service pipe, leading from the main to the house, had become entirely corroded and eaten away, so that it had to be replaced by new lead pipe. I did not give the matter the attention at that time that I would have done, had I any suspicion of the cause of the destruction of this pipe. Not very long after that, another leak was detected in that service pipe, and the party again made complaint. I had a part of the pipe and a basket full of the earth which surrounded it at that point of leakage taken out. An analysis was made, and from that analysis the chemist determined that there was nothing in the soil warranting the action upon the pipe, and that it must have been occasioned by electricity escaping from some conduit.

The first street railway which introduced electricity as a motive power, did not place any return wire between the tracks, nor did they with much care connect the rails. On the second line of road a return wire was placed between the rails—a very small wire—and the rails were connected with each other by copper wires. Some three months after the last report of the leakage in the service pipe, about ten o'clock one evening, I received a report of a break in the main, at about the same point where the service pipe had been reported as leaking, and which is directly opposite the powerhouse of what we call the West Side Street Railway line, and which was the first line that introduced electricity as a motive power. Upon examination of the pipe, we found one length almost entirely gone, another length adjacent to it pretty well corroded and eaten out. The pipe as soon as it was uncovered—and in fact the next morning—was so soft and spongy that the point of an umbrella could be easily pushed through it. I have here a section of the cast-iron water main it broke. You can see the action of the electricity upon it, and you can see on this edge how arly it came eating through the entire metal. There is hardly the ickness of a knife blade of metal left on this edge. On this side, nere you can readily see the oxidation, the iron was very soft when st taken out, and for a week after, so that it could be crumbled off ith the finger nail. In the course of time it hardened, and it is quite rd now. At one point where the water broke through, an openg was found in the pipe about four feet in length, and varying in dth from a half inch to two and one-half inches. The service pipe ows the action of the current in places working entirely through e metal.

Mr. Yardley: What was the thickness of that shell, originally?

President: Half an inch.

Mr. Keller: When you removed this could you tell whether the ick or thin part was up or down in the trench?

President: Knowing that I had something to combat, upon nich I had very little information, further investigations in the mat- were immediately made and it was found that the street railway mpanies had at every convenient point connected their ground wire, d also their ground rails, with the fire hydrants, without the knowlge of the city or any of its officials. Upon trying to ascertain how iny such connections were made, they admitted that there had been ty such connections made, which I discovered afterwards was a ictional part of the actual number that had been connected with e rails or return wire. I came to this conclusion, which is merely personal opinion, and may not be of any value; but I am undertakg to work upon it. The negative current, after having done its work the motor returns to the powerhouse either through the rail circuit, the rails are sufficiently connected by wires large enough to conict the current from one rail to the other, or by the return wire unrground, or by the connection through the hydrants to the mains. I ink it is well recognized that a wire will conduct a volume of elecicity, dependent upon the size or cross-section of the wire. It is nilar in its effects as a water pipe. A large wire or a return cirit, large in cross-section, will conduct, relatively, much more curnt than a small wire; like a large main conducting more water than smaller one. This return current will seek the nearest way through e line of least resistance back to the negative part of the generator; d the wire being insufficient to carry the entire amount, the surplus eks the next nearest channel, which is usually the metallic circuit rnished by our water mains. There is no action that I have been able to discover on the hydrant shell, by the conducting of the electricity on to the pipe, but the damage is done in the current attempting to leave the pipe in reaching the generator at the nearest point opposite the generator, and that in meeting with resistance, an electrolytic action takes place. The disintegration of the metal is caused apparently by the resistance of the current leaving the conductor, in its course directly over to the generator; and for that reason the action was first noticed upon the service pipe, and later upon the main, directly opposite the dynamos in the powerhouse.

I have, upon that basis, knowing it was the best thing that could be then done, made a compromise, which has been carried out to a large extent and will be still further carried out on the part of the railway company, viz.: that they will improve the connections which have been made with the hydrants, that they will reduce them to the number of fifty or thereabouts, connecting them through a copper band around the hydrants; that they will at the nearest point opposite their several power stations make a complete connection with the water main through a copper band, running a number of heavy copper wires directly to the generator, so as to offer the least possible resistance to the current leaving the water mains, with the view that there may be no action upon the water mains. It may not be of much importance what becomes of the current or how much resistance there is at a point away from the mains, as long as it does not take place at the point of contact of the water main with the ground. These connections are being made, and in order to still further facilitate the return current, they have agreed to run large copper wires to a larger main, one block from the powerhouse, so as to take up any surplus of the return current that may be moved along the larger water main, and which is not being carried quite up in front of the powerhouse through the smaller mains; and they will conduct that surplus to the powerhouse. I was hoping to be able to uncover these places where this break in the main occurred in order to ascertain what the action has been since the band has been placed around the main; but have had so many other matters on my mind that it escaped my attention, until yesterday. It is a place that ought not to be dug up during this time of the year, so that the examination will be postponed for about another month, when the main will be uncovered and ascertained what the action has been. I do not know that we shall overcome the difficulty entirely, but believe we will be able to reduce it to a minimum. In my own mind there is no question that the action is caused by the resistance of the current leaving the main; and if that resist-

ce can be overcome at that point, there will be very little, if any
tion, upon the water main itself.

Mr. Alexander: In connecting fire hydrants with a live current,
you should happen to have a fire at any of these places where the
lley wire is run, would not that make a short circuit, and possibly
ure the men?

President: The return circuit is not anything like the current
at is carried in the trolley wire. I do not believe there is suffi-
nt voltage in a trolley wire to kill a man or a child. There is in
e electric light wire, undoubtedly. I doubt, however, whether there
sufficient voltage or power in the trolley wire to affect a person;
e voltage does not exceed five hundred volts. This would shock
person, but would not kill. I do not think there is enough of elec-
city in the return wire to the hydrant to affect any fireman who
ght be handling hose at the hydrant.

Mr. Alexander: Suppose the current from the electric light wire
ould get in on the street railway current—come in contact with
e trolley wire—it would very likely kill every man who is hand-
g the hose.

President: There is no doubt that if the current from the elec-
ic light wire, through a stream of water, or through the trolley
ire, reaches a person it would paralyze or kill him.

Mr. Alexander: I think the scheme is a bad one, as there are so
any chances for injuring persons who may come in contact with the
ydrants or water pipes, in one way or another.

President: Our electric light wires are all buried in conduits.
hey are exposed merely where they come up through the pipe along-
de of the pole leading to the lamp, and the point of exposure there
merely from the top of the pole through to the lamp and return.

Mr. Diven: I would like to ask why you granted any conces-
ons to these people?

President: We granted the concessions to the street railway
mpany because they had from one to two hundred connections, and
did not know where they were, therefore to obtain control of them,
d know what was being done, they agreed to sever them all, and
connect them only at certain points, according to the plan shown
the map. The dark spots are hydrants which have been or are
w being connected, with the street railway return wire. They do

not, however, entirely depend upon the current passing along the water pipes. They are obliged to put in return wires, and only the surplus current, which the return wires cannot carry, is being passed off through our pipes. I thought this was the best way to get some information or knowledge as to where these connections were made hereafter; and if it is discovered that there is still electrolytic action upon the mains, after having made these connections more perfect, and after having returned the current through copper connections back to the generator, we will know where these connections are to be cut and keep them cut. We have that much information now, whereas we were absolutely at their mercy before. This is merely an experiment which may reduce the difficulty to a minimum. We have found no action, nor have we heard of any action upon any mains or service pipes, excepting immediately opposite or near the power stations.

Mr. Donahue: Without wishing to reflect in any manner upon the valuable papers that have been brought up for discussion at this meeting, I think this subject—electrolysis of water pipes—is by far the most important subject this convention can consider. I did not hear the remarks of Mr. Gardner, of New Orleans, but I understood that he suggested that a committee should be appointed to investigate this subject and present the information at the next meeting. If I have misconstrued his remarks, I would like to suggest that such a committee be appointed. This subject is one that few of us know anything about. I do not know of a subject that is more important to the water works superintendent or manager. We have had a state of affairs in our city for the last few months that has been very serious. The rapid development of the use of electricity for street car purposes has been shown in many of our small cities. You will remember, many of you, seeing in Louisville a few years ago a street-car sprinkler; a large tank on wheels designed for the purpose of sprinkling the streets. It was then propelled by horse power. They now have these sprinklers—which are very good things—on electric railways, and propel them the same as the cars. We have one in Davenport. We have been called upon to supply water to this electric sprinkler. We were compelled to make a five-inch connection to our mains. I hesitated very much in permitting it to be done, but we were compelled to do it. This electric sprinkler has a five-inch connection directly over our mains, this opening being placed between the rails of the double track. The object of having the large connection is to insure the rapid filling of the sprinkler. The railway company have a switch on their sprinkling car, by which they turn

the current from the trolley wires, while they are filling it.
ırse, there is no better conductor of electricity than water, and
ing this tank, even though they shut off the electric current, tl
· stands on the track with the trolley connection, and as the wate
ınection is within three or four inches of the negative or returı
·rent of the electric line which has the ground return or returı
l, you cannot have a more favorable condition for electrolysis oi
ter pipes than to be brought in direct connection with the positive
1 negative currents of this street railway. We have as yet experi-
:ed no difficulty, but are expecting it every day. I do not like to
:e up the time of this convention, and yet would like to get some
ormation. I took considerable time and trouble to make an inves-
ation of this subject, and found, after several weeks' study and
·respondence, that I knew less about it when I got through than
en I started. In all cities where there are electric lights, and espe-
lly street car service, I think this is a very important subject; and
vould like to suggest that we have a committee appointed to in-
ıtigate this subject and prepare a paper for discussion at our next
eting.

Mr. Gardner: My suggestion was that in some appropriate man-
the members of the Association be requested to contribute the in-
ıation needed and present it in the shape of a discussion at the
meeting. I think Col. Donahue's suggestion a good one, and I
: that of the committee so appointed the President shall be a
ber.

'he motion to appoint the committee was carried.

·esident: The incoming president will appoint the committee.

r. Mather: What was the object of your compromise with the
·ailway company? Was it because it was better to do that
han to get them, or to try to get them, to take the wires away?
ı think you could not accomplish that?

ident: I compromised; first, in order to obtain definite in-
ı as to where the connections were made, of which we pos-
knowledge whatever, and furthermore to overcome the dif-
my mind, as much as possible. This is not a permanent
se. If the method of returning the current from the main
icient, we have the right to sever the connections at any
ints that may be necessary. They have not a permanent
:onnect with the water mains through this compromise,

but I believe, gentlemen, that this matter can be adjusted; that it is not half as difficult as we imagine. It is merely a matter of returning the current. If the current is of low potential, it is not going to affect anything that is connected with our water mains, provided the current is conducted without resistance to the point where it leaves the mains. Do not let us make the question too difficult. The electrical engineers in the city here scorned the idea at first that the corrosion or action upon the mains came at all from the electric current. They denied it and fought it. I think they knew well enongh what caused it, but thus are not anxious to furnish information or light upon the subject, which will enable the water works superintendent to combat them with intelligent arguments. We have got to get at this information largely through our own efforts. The electrical engineer is working for the interest of the electrical company, and he is looking to their interest more than he is to the interest of the water or gas company. You will see that there are these samples that have been passed around; and you will observe especially with the cast iron pipe, that although the bulk of the current may be passed through the water, still there is not a particle of action on the interior face of the pipe; only upon the outer surface of the pipe and opposite to the powerhouse.

Mr. Mather: Does not a low potential become a high one in jumping from the water pipe to the generator?

President: I do not understand that it does; it depends on the resistance it meets with.

Mr. Mather: Would it not be better for us, if we could do so, to prohibit them from using the water pipes?

President: Certainly.

Mr. Mather. The first electric railway in our city used our water pipes for their return; but they removed their connections, for the sake of economy. They now have bond wires and carry the medium current between the rails. They asked me if I had any objection to their carrying it down by the large water mains—twenty-inch mains. In my ignorance I said "No." This was five years ago. The superintendent told me recently, that since these publications have been made in regard to it that they have removed them. They did not say anything to me about them, but they have removed them I believe on the ground of economy. They got their current back better by the bond wires connecting the rails. I think it would be better for us to use all the power we have to keep them away from the water pipes; still they have got to go somewhere, and as there is a greater attraction to the water main than to any other conducting substance, it usually goes there. We should be informed on this point. As Mr. Donahue says, I cannot conceive of a subject, except possibly, that of the preservation of health, that is more important to this body than the one now before us. I think the samples that have been shown are exceedingly interesting.

President: I do not wish to take up further time in this matter, but undoubtedly the proper steps to be taken are to prevent the connection with the water mains, if possible, and to induce the connecting of the rails with each other by thick and wide copper bands, so as to offer no resistance and be of a lasting nature, instead of the thin wire, which in the course of a few months begins to corrode; and also to compel the use of as large a return wire as possible. Places have been reported to me where the return current is neither conducted by any wire, nor where any connections have been made with the hydrants or with the ground, and yet the effects of electrolytic action have been noticed.

Mr. Decker: I do not know of any more decisive, more practical discussion of this subject that could be had, than the samples presented here by Mr. McAlpin, of Columbus, and Mr. Davis of Indianapolis; and I would move that the Secretary be instructed to have these photographed and reproduced in our proceedings, and that he obtain from Mr. Davis and Mr. McAlpin a description of the conditions under which this corrosion occurred.

Mr. Alexander: I would like to ask one more question; did you notice whether it was the top or under part of the pipe?

President: It was the upper quarter of the side towards the power station. The pipe is laid along the street directly opposite the powerhouse.

Mr. Mather: How far about, was it from the generator to the water pipe?

President: About 70 to 75 feet.

Mr. Mather: Of course there were rails running in and out on the surface?

President: Yes sir.

Mr. Woodward: Did the men receive any shocks in digging there?

President: No sir.

Mr. Dunham: Mr. President, you referred to the low voltage and its probable harmlessness. I think about five hundred volts are commonly used for street railways. While I could not cite any fatal cases, I know of several severe shocks, which the persons interested seemed thankful to survive. One man was knocked over by the contact of a piece of stove pipe with a trolley wire. I should think there would be sufficient current at all times, especially if the ground was wet, to make it serious for any one who received a shock.

President: Undoubtedly, if a connection is formed through damp or wet places, it will give the man all the shock he wants. However, I have seen a man take hold of the copper trolley wire with both hands and standing upon a dry board, he did not feel any shock.

RAIL BONDING

By H. R. Keithley

(Street Railway Review, November, 1893, Page 691)

The problem of rail bonding is not a question of first cost, it is a question of efficiency and permanent maintenance, for the expense of labor alone for rebonding the track is three or four times the first cost of copper. That is making the liberal allowance of $200 per mile of single track as first cost of copper for bonding a railway line with No. 0000 copper bonds. If the track is properly bonded with No. 0000 bonds the bonds will last as long as the rails. But if No. 0 bonds are used, costing $100 per mile of track, and required to do the work of No. 0000 bonds, the No. 0 bonds having only half the conductivity, will carry only half the current carried by No. 0000 bonds, and will furnish sufficient resistance to force the other half of the current into the earth. This leakage of current into the earth from the No. 0 rail bonds will cause their rapid destruction by electrolytic action, whereas the No. 0000 bonds would carry the current without leakage and they would not be destroyed by electrolytic action, and if properly connected into the rail, so that there would be no resistance at the joint, the No. 0000 bond would certainly last as long as the rails. But the No. 0 bonds would be destroyed in from three to five years and the cost of labor alone, for rebonding the track, taking up pavement and replacing it, would be from $600 to $800 per mile of single track, which is from three to four times the first cost of No. 0000 copper bonds, which is $200 per mile. Experience has fully demonstrated the correctness of this statement, for it is well known that all electric railways which bonded with No. 4 wire two or three years ago, are now obliged to take up the paving and rebond their track, at a cost of from $600 to $800 per mile of single track for labor alone. The system of grounding the track at intervals is not here considered, for the reason that electrical engineers and street railway mangers are convinced by experience that the earth return must be abandoned and the return circuit must be confined to the rails entirely, if possible, by use of heavy copper rail bonds, in order to prevent destruction of gas and water pipes by electrolysis, which is the direct result of using the earth for a return, and in order to prevent the destruction of their rail bonds by electrolytic action, resulting from the use of small bonds, capable of carrying only a small proportion of heavy electric railway currents.

(Engineering, December 15, 1893, Vol. LVI, Pages 738-739)

LETTER TO THE EDITOR OF "ENGINEERING"

By John M. Goodell, Worcester, Massachusetts

November 21, 1893

THE ELECTRICAL CORROSION OF UNDERGROUND PIPES

Sir: In the interesting description of the Marseilles and St. Louis Electric Railway, Dr. Preller mentions, on page 564 the danger of electrically corroding underground pipes and cables by driving the current through the rails, wheels, car wiring, trolley connections, and overhead wire rather than in the more usual overhead wire to rail order. In this country we have had an experience with such a method by operation in Cambridge, Massachusetts, one of the suburbs of Boston. There the wires, pipes, and house connections in the earth disappeared in a remarkably short time, and the tramway company was forced to reverse the direction of its currents in consequence.

Even when the current is sent out from the power stations through the overhead wires we are having considerable difficulty with electrolysis. In Boston and Brooklyn the trouble has generally been with the lead covering of the telephone wires, although in the latter city the water pipes are also affected. In Trenton, New Jersey, Columbus, Ohio, Saginaw, Michigan, Milwaukee, Wisconsin, and Sault Ste. Marie, Michigan, Los Angeles, California, and Hamilton, Ontario, electrolysis of the water pipes, both lead and iron, has been observed, and in most of the cities the officers of the water department or of the railway have kindly sent me careful descriptions of the corroded pipe, and such local condition as enable an opinion to be formed as to the nature of corrosion. It seems perfectly certain to me that the electrolysis occurs as follows: The return current through the rails and supplementary wires, if the latter are employed, reaches some point where the earth and the pipes embedded in it have less resistance than the metal circuit. Consequently the electricity follows along the pipes until the rails again offer a better path, when it returns to its theoretical path. From correspondence and personal observation of the effect of this fickle behavior of the return circuit, I am pretty certain that the electrolysis occurs at the points where the current leaves the pipes to return to the rail circuit, as might naturally be expected. The effect of the current is first to eat a series of little cavities in the surface of the pipe, which gradually enlarge until the metal may be completely destroyed around the entire circumference. A remedy that I have known to be applied successfully in a number of cases was to connect the pipes where corrosion was noticed with the rails of the tramway, so as to have a complete metal circuit. The leading remedy is one which the railways are slowly adopting as a matter of economy, without any reference to the wants of the water works, telephone, or gas engineer, viz., the better bonding of the rails.

The connection illustrated by Dr. Preller on page 499 is not considered the best practice in this country today, although it was was two years ago, when good bonding was not regarded as so important as now. In the single track illustrated the cross section of the two rails is about 10.8 square inches, which is equivalent in conductivity to about 1.6 square inches of copper, speaking approximately. To bond this track, there are two copper and two iron wires, each 7 millimeters in diameter, which have a total conductivity of about 0.14 square inch of copper. That is to say, the conductivity of the bond is only about a tenth of that of the rails. In this country we are now making the bonds heavier, and thus try to prevent the watts from straggling on their return home.

Yours truly,

JOHN M. GOODELL.

REPORT

OF THE

Board of Commissioners

OF

ELECTRICAL SUBWAYS

of the City of Brooklyn

DATED DECEMBER 15, 1893

Including a Special Report, Dated January 29th, 1894

BROOKLYN
1894

(The extract following consists of pages 7 to 15 of the original report.)

THE TROLLEY SYSTEMS

The conversion of horse car systems of street conveyance to the so-called trolley systems, is nearly complete within the city limits. Citizens are provided with a more comfortable means of street travel, but they are confronted with a new danger to life and limb when, as pedestrians, they cross the trolley car tracks. So much of the peril as arises from the inexperience of the motor-drivers is gradually becoming less, but all that belongs to the high rate of speed remains as a menace to the peace and comfort of the community. The danger increases in proportion to the increase in velocity. The citizen on foot has greater difficulty in avoiding collision and the motorman has greater difficulty in arresting the motion of his car. Much has been said and written about "fenders" and "wheel guards," but the experience of the last three months leads to the conclusion, that although fenders should not be dispensed with, the most pressing demand now is a more careful regulation of the speed.

If limited to the velocity of ordinary vehicles a trolley car in the hands of a competent motorman, is no more dangerous than the average express wagon or ice cart, and has as little need of a fender. The track which the car must follow, plainly marks the danger line. whereas the devious track of a reckless driver of a wagon defies human prevision.

It is urged, in behalf of the trolley, that the rules require the speed to be limited to an average of seven miles, and a maximum of ten miles per hour. But as delays are frequent, and as conductors and motormen are held to be culpable if the average is not maintained, it naturally happens that the motor driver will take advantage of a stretch of clear track, and exceed the prescribed limit of velocity. Cars habitually pass certain points on the principal trolley lines at the rate of twelve to fifteen miles an hour. In the opinion of this Board, the regulation of the speed is of more urgent necessity than the adoption of an appliance which shall trip and catch or pick up a citizen who is on the track. It is of importance to note that two lives have recently been lost by the impact of the car. The victim was not injured by the wheels. Such safety devices as have been thus far offered, would prove lastingly serviceable only under the condition of a perfectly level and smooth pavement between the rails and for a little distance outside of them. A continuously tinkling bell is also much needed as an additional warning, especially in the busier thoroughfares.

Regulation of the speed can probably be accomplished only by a mechanical governor which will limit the rate of the motor to that required to propel the car at the maximum legal velocity.

The erection of guard wires above the trolley wires has been insisted upon by this Board wherever there was danger of accidental contact with wires of another system. As a further measure of precaution it has been deemed expedient to limit the electric street lights to one side of the streets and avenues traversed by trolley cars. The ordinary plan of alternating the lamps requires many crossings by wires carrying high tension currents, whereby the danger of contacts is much increased. This change of plan has required that a large number of arc lamp posts be transferred from one curbstone to the opposite one; a work which is yet not quite complete.

The franchise under which the trolley lines are constructed and operated is construed to include the privilege of stringing the feeder cables along on the poles which are the necessary supports of the trolley wire. These cables must eventually be put in subways. A plan to bury a group of feeder cables in the southern portion of the city, early in the Summer, was frustrated by the unexpected opposition of the residents who objected on the ground that electric currents under the streets would endanger the health of the neighborhood. The temporary injunction granted by the Court delayed the work of equipping and completing the road, and so far inconvenienced the traveling public that a compromise measure was deemed expedient whereby a part of the system was carried on poles and the remainder on the elevated railroad.

CORROSION OF WATER AND GAS PIPES

One of the inconveniences incident to the introduction of the electric railway system was briefly referred to in the report of this Board for 1892, as of uncertain character and extent. It has proven to be of a very serious nature. This is the corrosion of gas pipes, water pipes and the lead covering of telephone cables. Wherever the destructive action has caused a leak, either of water or gas, the fact has been discovered and the injured section removed. These discoveries have of late been so numerous that there seems no escape from the conclusion that metal pipes of all kinds extending below the surface along the routes of the trolley cars are being in many places destroyed.

The cause of the difficulty is now well determined. In many other cities a similar experience has been recorded. The electrical experts are in accord regarding the origin of the injury. The electric current which propels the cars is discharged through the wheels to the rails. If the latter were continuous conductors the corrosion difficulty would not exist. But the imperfect contacts at the rail joints, even with the best devices for providing a path for the current around the joint, impairs the conductivity to such an extent that the earth in the vicinity becomes charged with the current which was designed for the rails, and plays to considerable extent the part of a return wire. Iron or lead pipes extending along the route below the surface become charged with the current. This condition involves a discharge at some point, and here the electrolytic action is established which, bit by bit, carries away the metal, or rather converts it into a compound which in the moist earth is readily detached. When this action is confined to a limited area, as at an abrupt bend in the pipes, the corrosion is rapid, but when it is distributed along a stretch of several hundred feet, as in the case of a Court Street telephone cable recently ruined by this means, the destructive action is slower but is, nevertheless, constant and sure.

A section of iron water pipe recently brought to the office of this Board exhibits a complete perforation which was caused in four weeks. It had been part of a service pipe lying four feet below the trolley track. It is evident that better means must be provided for the conduction of the return current of the trolley system. In a few cases, where a rapid local corrosive action has been discovered, the expedient of making a copper connection between the corroding surface and the return conductor between the rails, has been successfully tried.

A more comprehensive plan is in progress of trial on one or two of the electric railways in New England. It consists in welding the rails to continuous length of two thousand or more feet. The success of this experiment is not yet fully assured.

It should be said in behalf of the electricians of the trolley companies that there has been no lack of vigilance in aiding to discover the locations of injurious electrical action, or in applying the proper remedy.

In view of the fact that the problem of preventing electrical corrosion to service pipes underlying the trolley tracks is not yet satisfactorily solved, the proposed extension of electric system under a lately granted franchise may be regarded by the city engineers with some anxiety, as a portion of the route lies along the line of one of the largest water mains. Not only should absolute protection from electric corrosion be guaranteed by the Trolley Company, but constant watchfulness should be maintained without expense to the city.

A special report on the injury to telephone cables may be found in the appendix.

(Appendix)

THE NEW YORK & NEW JERSEY TELEPHONE CO.
General Superintendent's Office
16 Smith Street

Brooklyn, N. Y., December 13, 1893.

Hon. Board of Electrical Subways, Brooklyn, N. Y.

Gentlemen: In response to enquiry regarding the action of the escaping trolley current upon the lead covering of our underground cables I beg to say that five cables have been damaged so seriously, as to cause failure and their removal from the underground conduits on Court Street and on Flatbush Avenue. Investigation shows that cables on Atlantic Avenue, Third Avenue, Court Street, Flatbush Avenue and Manhattan Avenue are also affected but not yet seriously. The destructive action is due to electrolysis of the lead cover of the cable, caused by the current which reaches the cable covering through the earth on its way back to the dynamo, leaving the cable at points where the cable is positive to the earth. We have been able in some cases to reduce the trouble by connecting the cables to the return wire of the trolley road, on poles and underground between the tracks, but as the trolley system is being rapidly extended, and the location of the source of power and the direction of the current both subject to change, we have had much difficulty in securing tests upon which reliable action can be taken. Along Fulton Street, where the Elevated Railroad is used as part of the return circuit for the trolley current, we have so far suffered no injury, and it is probable that safety can be secured along other routes only by the use on the part of the trolley roads of copper returns supplementary to the rails of the track, and of sufficient size to carry the current which now leaks from the rails through the earth to all other metal conductors; much has been done in this direction by the several roads. Our experience would indicate that the safety of metal pipes of all kind, placed in the earth, as well as economy of operation, requires that the return system should be complete.

Respectfully yours,
J. C. REILLY,
General Superintendent.

SPECIAL REPORT

Brooklyn, January 29, 1894.

Hon. Charles A. Schieren, Mayor of Brooklyn.

Dear Sir: The Board of Commissioners of Electrical Subways begs leave to submit the following report as an appendix to the annual report submitted December 15, 1893. It relates to a single subject, viz.: the corrosion of water pipes, gas pipes and telephone cables by the return current of the trolley electric system.

The following report would have formed a part of the earlier communication, but the materials for it were not then obtainable.

The injury briefly referred to in the previous report can now be more completely specified and described by aid of the diagrams submitted herewith.

No. 1. The lead covering of a telephone cable in a conduit near corner of Court Street and Fourth Place. The cable laid in pitch on the bottom of the duct. The pitch proved no protection.

No. 2. The covering of a telephone cable in a conduit on Court Street between First Place and Fourth Place.

No. 3. Another portion of same cable as shown in No. 2.

No. 4. The covering of a cable in a manhole at corner of Atlantic Avenue and Smith Street. The failure of the cable afforded the first intimation of the injury. A heavy trolley current had apparently followed the cable and left for the ground at this point.

No. 5. From a cable under the rail of the Fifth Avenue trolley line near Flatbush Avenue. The same cable was also badly corroded at Bergen Street.

No. 6. From a cable between Carroll and President Streets in Court Street.

No. 7. An iron water pipe which had been in the ground under the trolley track in Second Avenue for about a year.

No. 8. An iron pipe used to replace No. 7 which had been destroyed by corrosion. The indentation and perforation which may be seen near left-hand end of pipe, were produced in thirty days.

No. 9. A lead water pipe taken from four feet below the surface on Second Avenue near Fifty-fourth Street.

The experience of Brooklyn is not notably different from that of Boston and Cambridge, Mass., Milwaukee, Wis., Columbus, Ohio, Indianapolis, Ind., and Hamilton, Ont. In each of these cities similar corrosions have been detected and in none is there any doubt as to the cause. It is known to be due to the imperfections of the means provided by the trolley companies for the conveyance of the electrical current back to the generator. It was at first supposed that the rails would be sufficient, but the current declines to take that route exclusively.

The remedy for the evil will have been applied when the trolley companies shall have provided an adequate route for the electric current now discharged into the rails. It was at first reasonably supposed that the rails would afford a sufficient path. Upon the failure of this plan, a copper connection to carry the current by the joint was tried. In most cases this expedient failed of complete success, except where the copper bond had unusual dimensions. An account of some experiments published in the "Electrical Engineer" may be profitably quoted here. "The resistance per mile of double-track road was found to be 0.7675 ohm in dry earth without bonds connecting the rails. Where the rails were bonded with iron wire of No. 3 gauge and cross-connected without a continuous return wire the resistance was 0.0797 with dry and 0.0717 ohms with wet earth. Where the track was formed with No. 3 copper wire bonds riveted to the rails, each bond soldered to a continuous copper wire of the same gauge and the rails cross-connected every 200 feet the resistance was 0.0207 ohm with wet earth. When the track was made in the same way as in the last example, but further improved by soldering the riveted bonds to the rails and spacing the cross-connections closer together, the resistance when the earth was dry amounted to 0.0254 ohm. Track bonded with two No. 4 galvanized-iron wires without a continuous return wire had a resistance of 0.0577 ohm when the earth was dry.

"These figures show that some bond is necessary, and furthermore that the resistance of the rail section is so slight that the calculated resistance of the bonds accounts for nearly all of that observed. This suggests a practical point, namely, the desirability of making the bonds larger than is now the usual practice and omitting the return wire. The effect of this wire has long been generally acknowledged to be small and its value to be chiefly as a supplement to the bonds.

There is a strong tendency now to do away with it entirely. It increases the conductivity of the return circuit somewhat, but probably not as much as if the metal in it were used to make larger bonds. A Johnson section 80, No. 254, girder rail for example, weighing 80 pounds per yard, has about the same conductivity as a copper wire 1¼ inches in diameter, while a section H, 60-pound Lewis & Fowler box rail has about the same resistance as a copper wire 1⅛ inches in diameter. No such amounts of copper have yet been used to make bonds, and until they have the possibilities of rail returns have not been exhausted. If the copper in the return wire in the third kind of track mentioned in the last paragraph were placed in the bonds the latter would be over an inch in diameter instead of 0.23 inch, and the actual conductivity of the return over thirteen fold greater. This shows that water, gas and telephone mains can be protected by better track construction, which will prove as advantageous to the railway company as to the other interests. This is one of the means of protecting mains from electrolysis, and suggests the following as a second method, which in most cases can probably be applied without much trouble.

"This second method is merely the connection by metal circuits of the water mains, gas pipes and telephone cables, to which some electricity will probably always pass, with the generators at the points where there is the least resistance to return currents. These are not necessarily the points where the distance between the pipes and the generators is the shortest, for it is possible to have this shortest line through dry sand and a line nearly a few hundred feet longer through moist earth with less resistance. The electricity of the return current would be apt to leave the pipes at the moist places under such conditions, and it is possible that the return metal circuit should be located here, although somewhat longer than at another point. Old rails, heavily bonded, have been suggested for such a use, and would probably prove satisfactory."

It should be said in regard to this second method, that in making connections with the underground systems of pipes and cables that the points of such connections would require frequent examination. A copper connection with an iron pipe underground would not long remain a reliable conductor, unless special care and watchfulness were given to it.

A better way to insure the conduction of the current is doubtless to make the car rail continuous by welding. This method will be employed on the new trolley line soon to be built in the southern part of the city.

The most complete solution of the problem is afforded by the double trolley by which the return current is provided for by an overhead wire similar to the one for the outgoing current. But it is to be hoped that it will not be necessary to resort to this method.

Some notes of experiments obtained through the kindness of Mr. I. H. Farnham, Electrician of the N. E. Telephone Company, and relating to the early experience in Boston are here given.

"When the action of the current was first noticed, the experiment of grounding the cables to lead plates buried in manholes, was tried on quite an extensive scale, but was soon abandoned as being impracticable. The quantity of electricity to be dealt with was so enormous that the buried plates offered no appreciable protection to the cables. If such a system were feasible, the expense for the constant renewal of plates would be very large.

"The severity of the action may be diminished, to a certain limited extent, by so arranging the direction of the current used for the street railways, as to make it pass out over the trolley wires, and back through the ground. In this way the direction of the current would be quite generally, from the earth to the cable, thus diminishing in certain places the corrosive action. This method would not be a complete protection from the corrosive action, as there would be places where the current would still flow from the cables. Even though the current is uniformly to the earth from the cables, there is the possibility of an action caused by alkaline substances formed about a cable, due to the decomposition by the current from the street cars of the soluble salts contained in the surrounding earth. These alkaline substances are capable, under certain conditions, of dissolving the lead, when the currents are shut off or much reduced, as would be the case at night.

"As there has been some misunderstanding in regard to the potential measurements made in connection with the numerous corrosion investigations, it should, perhaps, be impressed upon those who are about to carry on similar investigations, that the potential measurements between the cables or pipes, and the material surrounding them should, in the majority of cases, only be looked upon as indicating the direction in which the current tends to flow.

"To say that the pipes and cables are even practically safe from corrosion, when the measurements are below a specified figure, would be extremely misleading. These measurements are, in a certain sense, like the measurements which might be made in an electrolytic cell, between one of the electrodes and various portions of the electrolyte, so that it is possible to conceive of almost zero potentials in the immediate vicinity of the most violent electrolytic corrosive actions.

"The fact should be closely borne in mind that whenever we have a current passing from an easily oxidizable metal to the liquid, such as would be encountered in the earth corrosion is bound to occur.

"A large number of electrolytic experiments have been carried out, showing the extremely low potentials (measurements between the electrodes) at which corrosion is found to take place. In many cases iron and lead were destroyed under the conditions encountered in the underground systems at potentials considerably under .5 volt."

The conclusions fairly drawn from these notes and from our own experience is that considerable injury is being done to underground pipes and cables, and that it will continue along the lines of the trolley roads (except where the elevated railway extends above them) until better methods of returning the current to the generator are put in practice.

The electricians of the several trolley roads are fully aware of the situation and have speedily applied means of prevention in localities where the corrosion had been detected. But it is doubtful if the method of final cure of the difficulty has yet passed the experimental stage.

Respectfully submitted,

GEO. W. PLYMPTON,
FRED R. LEE,

Commissioners.

TO THE EDITOR OF "ENGINEERING"

(Engineering News, January 5, 1894, Page 24)

Sir: I quite agree with Mr. Goodell's remarks in his letter on ıe above subject, printed in your issue of December 15. The sec- onal area of the Marseilles and St. Louis girder rails works out, as e says, at 10.8 square inches for the two rails of single line; nor can ıere be any doubt that, as in a properly designed permanent way, ıe joint should be as heavy and stiff as the rail itself, so also should ıe electrical joint or wire-bond have the same conductivity as the ail forming part of the circuit. In the case of the Marseilles line, the eficiency of conductivity of the wire-bonds, in respect of that of the ails, is to a great extent, if not wholly, made up by the complete ıetallic system formed by the permanent way itself, viz., besides the ails, by the stout alternate joints, the chairs, and the metallic sleep- rs; whereas in an ordinary tramway laid with girder or other rails 'hich rest direct on the ground without intermediate longitudinal r transverse bearings, wire-bonds of much higher conductivity are, f course, required to prevent extensive leakage, and the consequent orrosion of pipes in proximity of the line. It would be interesting know what is the distance below the rails of the pipes which have 'en largely affected by electrolytic action along the tramway lines which Mr. Goodell refers.

Yours faithfully,

C. S. DU RICHIE PRELLER.

18 Margaret Street, Cavendish Square, West.
December 18, 1893.

'OKLYN, N. Y., CLEVELAND, OHIO, LOUISVILLE, KY., AND CINCINNATI, OHIO

(Engineering News, January 11, 1894, Pages 37 and 38)

orrosion of water pipes and other underground furniture by the l return of electric railways continues to be reported. The re- ınual report of the Brooklyn Electrical Subway Commission hat discoveries of corroded water and gas pipes have been of numerous that there seems no escape from the conclusion that 'pes of all kinds extending below the surface along the routes 'olley cars are being in many places destroyed by the ground The lead covering of the telephone cables in the subways ıffering from corrosion. Other instances of serious corrosion of telephone cables are reported from Cleveland, Louisville and Cincinnati. At Peoria, Ills., the Peoria Water Company has formally notified the city authorities that its mains are being injured by the currents from the street railways, and unless these ground currents are removed the water company will refuse to make further extensions of its mains or to be responsible for the maintenance of those now laid.

NOTES AND QUERIES

(Engineering News, January 11, 1894, Page 33)

R. W. P. asks for particulars as to the corrosion of underground pipes by the return current of electric street railways. He will find such particulars in our issues of Sept. 22 and Dec. 29, 1892, and Sept. 14 and Sept. 28, 1893. In brief, the facts are that considerable corrosion of underground pipes has been caused by the return current of electric railways. The best practice in constructing such railways at present, however, is to furnish a metallic path for the return current, either through the track rails or through independent return wires. With such a metallic return, properly constructed, any ground currents which might occur through leakage would be so very weak as to be incapable, so far as can be seen, of doing any material harm.

ST. LOUIS, MISSOURI

(Engineering News, January 25, 1894, Page 268)

Engineers' Club of St. Louis—At the meeting on January 17 the following program for 1894 was announced: Jan. 3, "Street Railways," Winthrop Bartlett; Jan. 17, "Street Railways," George R. Olshausen; Feb. 7, "Washington University Testing Laboratory," J. B. Johnson; Feb. 21, "Manchester Ship Canal," John Dean; March 7, "The New Water Works: 1, General Features," M. L. Holman; March 21, "The New Water Works: 2, The Extension," S. Bent Russell; April 4, "The New Water Works: 3, New Machinery," J. A. Laird; April 18, "The New Water Works: 4, Quality of the Supply," Robert E. McMath; May 2, "The New Water Works; 5, The Problem of Filtration," Robert Moore; May 16, "Punching as a Means of Testing Structural Steel," Theodore L. Condron; Sept. 19, "Sharp Curves in Railway Yards," E. A. Hermann; Oct. 3, "Motions of Soaring Planes," Dr. C. M. Woodward; Oct. 17, "A Method of Determining Sewage Pollution of Water," Chas. C. Brown; Nov. 7, "Progress in

Steam Engineering," Col. E. D. Meier; Nov. 21, "Report of Committee on Smoke Prevention," W. B. Potter, Chairman; Dec. 5, Annual Meeting; Dec. 19, Announcement of election. Address of retiring president.

Mr. George R. Olshausen addressed the club on "Street Railways," dealing particularly with special work in track construction. He called attention to the great improvements which had been made in this direction in the last four years, and exhibited drawings of standard switch and crossing construction, and described a method of designing casement curves which he had found very satisfactory in practice. The form used was a spiral. The Union Depot Co. uses a rail weighing 100 lbs. per yard on curves, and a 75-lb. rail for straight track. The necessity for a better form of brakes was discussed, the present types described and the practical experience with each stated. It was shown that what was needed was a quick and powerful application of the brake at first, while the car was still running fast. It was shown that if the rail was well bonded there was no necessity for supplemental return wires or other grounds. The electrolytic effect of the return current on water mains was explained, and it was thought this could be remedied by connecting the rails thoroughly to the pipes by copper wires.

Mr. Morrell, engineer of the Lindell Ry. Co., stated that in his opinion the best return was to weld each pair of rails together with two 0000 copper wires, and then connect the rails to the generators at the station without any other attempt at grounds.

WM. H. BRYAN, Secretary.

(Engineering News, April 5, 1894, Page 273)

St. Louis water mains are being corroded by electric ground currents. The first serious injury was discovered on March 28. A 6-inch iron main was discovered with a section badly corroded by the return current of the St. Louis & Suburban Railway. It is supposed that other places on the mains have been similarly injured and that leaks will develop soon.

NEWARK, NEW JERSEY

(Engineering Record, Feb. 1, 1894, Supplement Page 102)

The Electrolysis of Water Pipes has been causing considerable trouble in Newark, N. J., and some months ago the city engaged Mr.

Harold P. Brown to examine into the matter and suggest a remedy. He submitted a report on December 6th in which some interesting facts were given concerning the methods adopted to diminish the corrosion. Three of the dynamos in the Boyd Street power station of the railway were adjusted to give 12 volts higher pressure than the remainder and their negative terminals were connected to a large copper feeder wire leading to water pipes on Belmont and Eighteenth Avenues, where the mains were found to be positive to the tracks, the difference of potential being about seven volts. After the connections were made the mains became negative to the track and from 1½ to 3 volts difference of potential was noted. This change resulted, according to Mr. Brown, in a saving of from 60 to 100 horsepower in the total load on the dynamos, which is another confirmation of the opinion of "The Engineering Record" that the street railway companies will find it profitable to build their track and return circuits so as to practically prevent serious corrosion.

(Engineering News, September 6, 1894, Page 183)

Electrolysis of water and gas mains in Newark, N. J., is to be remedied by the street railway companies by methods to be agreed upon between experts selected, one each, by the companies and the Board of Public Works.

OMAHA, NEBRASKA

(Engineering News, February 1, 1894, Vol. XXXI, Page 81)

The electrolysis of iron and lead water pipes, by the escaping current from the trolley lines, is now seriously troubling the authorities of Omaha. The lead pipe is honeycombed only in spots; but the iron pipe is completely disintegrated in places, and can be "as easily whittled with a knife as roofing slate," says the Omaha "Bee." The damage is particularly marked in the immediate vicinity of the powerhouse. City Electrician Cowgill says that the current escapes from the tracks and takes to the pipes, imbedded in moist earth, as an easier path back to the powerhouse; and the concentration of current near that point causes the greater damage referred to. He also notes that the iron trolley poles are rusting at the ground faster than hydrants, etc., in the same soil and neighborhood, and believes that this is caused by imperfect insulation and a consequent leakage of current. The only way to stop these various troubles is, of course.

to provide ample metallic conductors for carrying the return current back to the dynamos.

(The Engineering Record, February 24, 1894, Page 200)

The Electrolysis of Some Underground Pipes in Omaha, Neb., principally in the vicinity of the powerhouses, forms the subject of an interesting report made by M. J. Cowgill, City Electrician, and sent us by City Engineer Andrew Rosewater. At one point the pipe affected was about 4½ inches deep. The return electric wires ran parallel with it just under the paving blocks and were connected to the rails of the cable line. The wires used were estimated to be two No. 00. No drop was found between them and the rails, which showed good electrical connection between them, but between the rails and the pipe there was a difference in potential of 10 volts. When the ammeter was connected the current was found to average about 100 amperes. As the ammeter had a very low resistance, the difference of potential as shown by the voltmeter, when the connection between the pipe and wires was made in this way, was only three volts. Consequently Mr. Cowgill advocates connecting the rails and pipes with wires of ample conductivity, and if this connection is liable to be destroyed, to have it so that it can be examined.

(The Engineering Record, December 22, 1894, Page 57)

Electrolysis Nodules such as frequently appear in cast-iron pipes near electric street railways have been analyzed by Mr. Joseph Rigge for Maj. J. B. Furay, Sewer Commissioner of Omaha, Neb. One nodule of a specific gravity of 1.88 was found to contain 56.17 per cent of iron, 29 of graphite, 1.15 of manganese, 13.37 of silica, and 0.29 of sulphur, phosphorus, and other substances. The effect of the electrolyzing current will be noticed when the above analysis is compared with that of fair gray iron, which has about 90.5 per cent of iron, 3.75 per cent of uncombined carbon, and 4.14 per cent of silica.

(The Electrical World, January 19, 1895, Vol. XXV, No. 3, Page 82)

Analysis of Electrolyzed Pipes—A paper, by Mr. Rigge (Omaha), is reprinted in "L'Elec.," Dec. 28. He gives the results of some measurements of the voltage and current in the earth return; the article contains, word for word, the description of the analysis attributed in another journal (see below) to Mr. Furay. As a remedy against electrolysis he suggests reversing the current frequently, "if it were safe and possible"; it is impracticable to insulate the pipes, and the only practical way which occurs to him is to weld the rails or to bind them with one-inch copper wire. He suggests that frequent voltage measurements should be made all over the line, and that changes in the return conductor should be made as the measurements may indicate.

(The Electrical World, January 19, 1895, Vol. XXV, No. 3; Page 83)

Electrolyzed Water Pipes—An abstract of a paper, by Mr. Furay, read at the Montreal meeting of the Fire Chiefs, is contained in the "Electric Age," January 5. He gives the result of an analysis of the material found on underground iron pipes, that had been acted on by the current; he found that the specific gravity was very small, 1.88; the material it contained about 56 per cent of iron, 29 of graphite, 1 of manganese, 13 of silicon, besides sulphur, phosphorus, etc.

SOUTHAMPTON, ENGLAND

(The Engineering Record, Feb. 8, 1894, Vol. XXXI, No. 7, Page 122)

Electrolysis of a Gas Service was detected at Southampton, England, in October of this year, which was found to have occurred in an unusual manner. The wires of a local electric lighting company are carried in a conduit in which there are at frequent intervals cross-bridges to keep the bare conductors from resting on the bottom or touching each other. At one place a gas service crossed the conduit below the conductors. A gas leak was detected in the vicinity and on an examination being made it was found that one of the conductors had sagged so as to strike the stoneware tile inclosing the service. This tile was punctured with a crater-shaped hole which extended completely through the gas pipe and allowed the gas to escape into the conduit. The conductor had been fused and its two ends lay on the bottom of the duct. The accident, according to Mr. S. W. Durkin, of Southampton, occurred on a service pipe but three years old, and he states that the area of the opening in the pipe was about seven-tenths of a square inch.

WILMINGTON, DELAWARE

(Engineering News, March 1, 1894, Page 169)

Electrolysis of water mains is said to be making havoc with the

Wilmington, Delaware, water pipes. On a street in which an electric railway ran, a 6-inch main was found to be badly perforated, holes as large as 1½ inches in diameter being found. The service pipes along the main were also affected. 40-ounce lead pipe being corroded to 12 ounces..

PEORIA, ILLINOIS

(Engineering News, March 22, 1894, Page 242)

CORROSION OF WATER PIPES BY ELECTRICITY

Sir: By this mail I send you a sample of earth that may prove of interest in view of the ever-increasing importance of the question of the electrolysis of lead and iron pipes by the return currents from trolley line. The sample referred to was taken from near a lead service pipe, buried over 5 feet in the ground, under the tracks of one of the electric railway companies in this city. The pipe was pitted deeply over its entire length, the injurious action being noticeably greater near the tracks, and diminishing towards the curb-line. At a point nearly under the tracks the pipe burst, being here eaten almost through. I regret being unable to send you a pieec of the pipe; but we are saving it, along with many other lead and iron service pipes, which have been similarly destroyed, for future use.

You will note that the sample of earth sent you shows on one side a lead-coated impression made by the pipe as it lay in the earth; while all through the sample may be seen the lead, deposited in fine powder or crystals, very like silver-lead ore. Should the lump of earth be pulverized in transit, you will, if you will wash a little of the earth just as a California miner washes a pan of gold-bearing gravel, obtain a residue of a good many "colors" of lead.

It seems to me that the sample of earth shows very clearly just how the electrolytic action takes place.

Yours truly,

DABNEY H. MAURY, JR.,
Supt. Peoria Water Co.

Peoria, Ill., March 15, 1894.

(The earth has been received and fully corroborates what Mr. Maury says above.—Editor.)

BROOKLYN, N. Y., BOSTON, MASS., CAMBRIDGE, MASS., MILWAUKEE, WIS., COLUMBUS, OHIO, INDIANAPOLIS, IND., AND HAMILTON, ONTARIO

(Engineering News, March 29, 1894, Page 255)

ELECTRIC CORROSION OF WATER PIPES IN BROOKLYN, N. Y.

The serious effects of the return currents of electric railway circuits have been made very evident in Brooklyn, N. Y., as in other cities, by the corrosion of gas pipes, water pipes and the lead covering of telephone cables, and the Board of Commissioners of Electrical Subways in its report for the year ending December 15, 1893, referred to this matter and recommended that the railway companies should be required to guarantee absolute protection from electric corrosion, or electrolysis, and that constant watchfulness should be maintained without expense to the city. In January the board submitted to the mayor a special report on this subject, accompanied by specimens of corroded iron and lead pipe, and leaden cable coverings. The commissioners are Prof. Geo. W. Plympton and Fred R. Lee, and an abstract of their special report is given below: The experience of Brooklyn is not notably different from that of Boston and Cambridge, Mass., Milwaukee, Wis., Columbus, Ohio, Indianapolis, Ind., and Hamilton, Ont. In each of these cities similar corrosions have been detected and in none is there any doubt as to the cause. It is known to be due to the imperfections of the means provided by the trolley companies for the conveyance of the electrical current back to the generator, and the remedy for the evil will have been applied when the trolley companies shall have provided an adequate route for the electric current now discharged into the rails. It was at first reasonably supposed that the rails would afford a sufficient path, but the current declines to take that route exclusively. Upon the failure of this plan, a copper connection to carry the current past the joints was tried. In most cases this expedient failed of complete success, except where the copper bond had unusual dimensions. An account of some experiments published in the "Electrical Engineer" may be profitably quoted here.

(Engineering News, April 5, 1894, Page 273)

A water works stand pipe, at Peoria, Illinois, burst and fell on March 30, and the flood caused considerable damage. One man was killed and several were injured, three fatally. A full report of the accident is given in another column.

ST. JOSEPH, MISSOURI

(Engineering News, April 26, 1894, Page 352)

The latest case of serious electrolysis of water mains by electric railway ground currents is reported from St. Joseph, Missouri. Besides the city mains, the pipes of the Artesian Ice Company have been affected.

BROOKLYN, N. Y., CAMBRIDGE, MASS., LOUISVILLE, KY., AND CLEVELAND, OHIO

(The Engineering Record, May 26, 1894, Page 414-415)

THE ELECTROLYSIS OF PIPES

The discussion in the institution of Electrical Engineers on the valuable paper by I. H. Farnham, entitled "Destructive Effect of Electrical Currents on Subterranean Metal Pipes," and reprinted in "The Engineering Record" of May 5, brought out many interesting facts. Prof. George W. Plympton, of Brooklyn, was the first speaker, and at the outset he stated that in his city the electric railways have to bear the responsibility for any damage to underground cables and pipes. He questioned the value of Mr. Farnham's seventh conclusion, which reads as follows: "A large conductor extending from the grounded side of the dynamo entirely through from the danger territory and connected at every few hundred feet to such pipes are are in danger will usually insure their protection." Professor Plympton agreed with this statement as long as the connections between the conductor and the pipes remained intact, but he was of the opinion that the connections would not last long and would require frequent repairs.

Several of the conclusions in the paper were discussed adversely by A. E. Kennelly. He believed that it was not necessarily good policy to connect the positive pole of the dynamo to the trolley lines, for the following reasons:

Suppose you ground one terminal of your dynamo which is supplying a total current of 1,000 amperes, that 1,000 amperes goes into the ground on your district and has to come out of the ground on your district, and it has to come out of the ground at the point of your ground connection to the dynamo. Now if you bury in the ground a large mass of metallic conductor of any kind, that conductor will absorb a large fraction of the current, say 750 amperes. Now, when you have the negative pole connected to the line, the current will go from your ground plate, will enter all this mass of metal in the vicinity and there it will do no damage. But it will issue from the iron or lead over a larger area in the remote districts. There will be danger of corrosion in that area and there will be active electrolysis going on all over it to the extent of the 750 amperes. But when you reverse the current you reverse that condition of affairs. All the distant district is free from danger, and all the oxidizing and corroding effect is close to you, but the 750 amperes are still there and are now actively corroding a much smaller surface. The danger area is reduced, but the danger is greater. You have, say, 20 times the amount of corrosion going on over a given surface of pipe. If we prevent this by throwing out ground feeders to prevent the current from passing from the pipes to the soil, then all is well. But unless this is done you are likely to have more trouble than if the negative pole were attached to the line.

Another point debated by Mr. Kennelly related to the difference of potential necessary to produce corrosion. He claimed that a voltmeter reading between the lead covering of a cable and the ground in its vicinity is not necessarily a criterion of the corrosive activity in the vicinity. If the cable is positive, there will be a tendency to produce corrosion, but if the difference of potential is three to four volts, the corrosive current is not therefore twice as strong as if the difference were 1 volt to 1½ volts, since the quantity of current passing from the cable to the earth may be much less on account of better insulation. Attention was also drawn to the fact that the resistance of the ground is really quite high and it is the water in the ground which produces the low resistivity.

In answer to the argument of Mr. Kennelly, that by connecting the positive pole of the generators to the line the corrosion of pipes would become serious, Mr. Farnham said that the question to be decided was essentially whether it would be more convenient to dig up all the paved streets of a large city once in 10 years, or to dig the streets within a radius of 1,000 feet to 2,000 feet of the power stations once a year. He considered it much better to confine the electrolysis to a definite small area than to scatter it over an area of indefinite extent. The same opinion was advanced by Thomas D. Lockwood, who stated, however, that in a small town the local conditions might ke it preferable to connect the negative pole of the generators to line.

Prof. Elihu Thomson sent the following letter on the subject, ich is of considerable interest on account of the novelty of some the suggestions:

Could every line of pipe be relied upon as a complete conductor hout bad joints, the problem of protection would be much simpli-l, but the current in crossing a bad joint in a line of pipe will un-ıbtedly be partly shunted through the earth around the resisting ıt, and cause corrosion to a greater or less extent. Again, if in a : of pipe every joint was of poor conductivity, there would be very le chance of corrosion by electrolysis, as the pipe line would not :r any good path for current.

Earnest endeavors will be made in the present year to prove the cticability of continuous rails welded in place electrically. In es this would give a network containing a vast amount of metal in rails acting as a conductor for the return current. Such a track tem, or even a track well bonded, would if worked with a zone tem, in which successive zones of trolley conductors are made itive and negative respectively, remove all possibility of trouble, might increase the risk in the accidental crossing of wires on the lley conductors. Another system of working which would remove st of the difficulty in our cities would be the employment of poten--reducing motor generators at various points over the area, the h potential side being fed direct from the power station by a metal-circuit with alternating or continuous current, as is found most ıedient, while the low potential side, 500 volts or less, would go to trolley wire and track respectively. In this case the return cur-t would never have far to travel, and the drop on the whole sys-ı would be much lessened. Copper would be saved and the con-ted districts could be readily supplied with a lower potential than high-speed outlying districts. If alternating currents were used m the power station to the motor generators, the generators in the tion could be made of very large capacity, say 5,000 horse-power in arge city, and the motor generators could range from 200 to 500 sepower, according to the density of traffic. I mention these facts show that avoidance of all electrolytic corrosion is within the capa-ties of electric engineering, while still retaining the continuous rent motors on the cars and the single overhead trolley wire. It even possible that considerable economy of transmission might be ured over the direct-supply system as now used.

The electric welding of rails, which has been so strongly advocated as one of the preventives of electrolysis, was the subject of a long series of experiments during the last summer and winter at Cambridge, Mass. The results of the experiments are described in a communication by Hermann Lamp, Jr., who states that the tracks where the tests were made had been previously condemned by the railway company. Of the welds made on one street, about 10 per cent have broken during the winter, but better results are expected from the improved methods of welding now adopted. The tests made thus far are stated to indicate: First, that a continuous rail can be used for electric street railway practice with absolute safety if an expansion joint is inserted every 600 feet; Second, that a continuous rail can probably be used without any expansion joint by adopting the latest method of welding; Third, that the electric conductivity of any joint is as great as that of the rail itself; Fourth, that all joints being of the same material and continuous, even when elastic, will not change by vibration, heating, or electrolysis; Fifth, that by frequently cross-connecting the rails so as to make up a track of electrically welded joints, any trouble from interruption in the track can be obviated; Sixth, that the resistance of the feeders from track to powerhouse is immaterial aside from economy, provided the ground in the powerhouse is taken off.

The effects of wandering currents in Louisville and the vicinity were described by A. T. Welles, of the Western Electric Company. Two telephone cables near one of the power houses of the electric railway began to give trouble after less than a year of service, and on pulling them partly out of the pipe conduit in which they were laid it was found that the lead covering was eaten through at regular 18-inch intervals, corresponding exactly with the joints in the pipe. A number of tests in manholes near the place of the trouble showed a difference of potential running as high as 2½ volts between the cable and the rails, and the gas and water pipes in the manholes had about the same voltage. The underground telephone cables run from all points of the compass to the company's office. About 30 are practically bunched near the exchange so that any currents coming in on their sheaths can reach those of such cables as will return them most readily to the powerhouses. All of these cables run parallel with trolley lines or with gas or water mains which parallel the trolley, so that each carries to the common point more or less current. Taken singly, these currents are slight and would probably cause no trouble for a long time, but one-half or two-thirds of their total amount was sufficient to eat through the sheath of the cable in seven or eight months. In Cleveland, Ohio, Mr. Welles found a telephone cable which gave t in ten weeks from electric corrosion. In ran from the exchange about 1,500 feet to a tunnel about 80 feet deep under the river, rough which a large water main also runs. Voltmeter and ammeter ıts in the tunnel showed that there were 18 or 19 volts on the cable d main in the tunnel, and 45 amperes current.

In a consideration of the return system for an electric road, A. V. ›bott stated that the railway company should not forget that by oviding an adequate return circuit which will protect other underound structures, they are not only securing immunity for them ves from damage suits, but at the same time are putting more oney into their pockets in a saving of coal than the interest and depreciation upon the investment involved in the return circuit ll amount to. In building some 300 miles of electric road Mr. Abtt has always found that the grounded return circuit absorbed more ergy from the station than any other part of the line, the car motor ly excepted. In one instance the return circuit of the road was so or, owing to defective rail bonding and the dry condition of the il, that in many instances the rail bonds had actually burned their ıy through the ties of the road, and allowed the rails to separate another instance, motor repairs were reduced several hundred dol's a month by the addition of an appropriate amount of feed wire a third case, the amount of power required for operation was much duced by the provision of an appropriate return.

NEW BRUNSWICK, N. J., SAN FRANCISCO, CAL., NEWBURG, N. Y., BOSTON, MASS, CINCINNATI, OHIO, AND ENGLAND

(Engineering News, June 7, 1894, Page 472)

THE ELECTROLYSIS OF PIPES

The electrolysis of water, gas and other metal pipes laid in the [illegible] reets through which pass trolley systems of electric cars is receiving an increasing amount of attention all over the country. [illegible] an Cleef, Mayor of New Brunswick, N. J., recently vetoed an ordinance granting a franchise to a street railway company, one of the hief grounds for his veto being that the ordinance [illegible] uard against electrolysis. The water and gas companies of San rancisco, Cal., are much exercised over the dangers [illegible] n that city, the gas company having [illegible]. The water ommissioners of Newburg, N. Y. have been considering [illegible] through their engineers, Messrs. John D. Van Buren and Everett Jamison, with Mr. I. H. Farnham, M. Inst., Elec. E., regarding the protection of their water mains against current from a trolley railway now under construction. In numerous other cities investigations are being made and papers on the subject are appearing at frequent intervals before engineering societies and in technical journals (see Eng. News, Sept. 22 and Dec. 29, 1892; Sept. 14 and 28, 1893; Jan. 11, Feb. 1, March 1, 15, 22 and 29, April 26, May 3 and 24, 1894). A paper entitled "The Electrolysis of Water Pipe" is to be read on June 14 by Mr. C. A. Stone before the New England Water Works Association and one on the same subject was read last fall before the American Water Works Association by Mr. Peter Milne, and only a few days ago the Pacific Coast Gas Association appointed a committee to investigate the subject.

The matter is one to which the water works and gas associations of the country, as well as the various electrical societies, should give immediate and earnest attention, as they no doubt will.

There is a growing disposition to hold electric railway companies responsible for damages caused by ground currents and a crop of lawsuits over the points involved is likely to develop at an early day. In one sense the trouble may be said to have only just begun, owing to the recent construction of many trolley lines and the lack of attention which has been paid to the subject.

The trouble which these ground currents from electric railways are causing may perhaps eventually lead to a return to the double-trolley system of electric traction. In this system, as most of our readers doubtless know, there are two parallel overhead wires, placed 12 to 18 inches apart. One wire leads to the positive pole of the dynamos at the power station; the other to the negative pole. There are two trolley poles on the car roof, one to each wire and the circuit is down one pole through the motors and up the other pole to the return line. The system has been very thoroughly worked out in Cincinnati, and has been in successful operation on street railways in that city for some years. Of course its first cost is considerably greater than the cost of the single trolley system, when installed in the ordinary way that such systems have been installed, with little or no provisions for the return circuit beyond grounding of the rail and flimsy bonds, which were practically valueless. It is said, however, that if the single-trolley system is built with thoroughly bonded rails and with independent underground wires for the return circuit, equal in conductivity to the outgoing side, the single-trolley system will cost at least as much as the double-trolley system. When it is considered that the double-trolley system absolutely eliminates interference with telephone and telegraph circuits using a ground return, besides preventing all the corrosion of underground pipes, there is much reason for believing that a return to the double-trolley may be the part of wisdom. As we have before pointed out, with even the best provision for the return current which it is practicable to make, a certain amount of leakage is inevitable if the rails are made part of the circuit, since they cannot be actually insulated from the ground. Thus while the danger of the corrosion of underground structures can be greatly reduced, it cannot be wholly eliminated so long as the single-trolley system is used. But for all this the single trolley will remain in use and the difficulties connected with it must be met and overcome as far as possible.

As noted in a recent issue, English engineers have taken warning by experience with electrolysis on this side of the water and the Board of Trade has laid down various requirements for the control of the circuits of electric street railways. In the course of the discussion before the Board of Trade during the drawing of the regulations, the question arose—whether the wandering earth current from an electric railway might not reach the track circuit of a block-signal system on a steam railway line, set the signal at safety when it should be at danger, and thereby cause a serious accident. In ordinary signaling practice, the semaphore drops by gravity to the danger position and is raised by an electric current to safety. When it is remembered that the wandering earth current of electric railways is sufficiently powerful to work electric bells and telegraph instruments, and has even in some cases, we believe, been made use of for incandescent lighting, the possibility that, under proper conditions, such a current might cause a semaphore to show a wrong indication, would seem to be by no means remote. It is true that no instance of this sort has thus far been made public; but it is to be remembered that electric railways are still a novelty and little used outside of the United States, and that only a fair beginning has been made in the equipment of this country's railways with block signals. Besides this, many things occur in railway service which are long in being made public, and because no instance of the turning of a semaphore in the manner described is on record, it does not, therefore, follow that none have occurred or may not occur in the future.

SAN FRANCISCO, CALIFORNIA

(The Engineering Record, June 9, 1894, Page 20)

NOTES

The Electrolysis of Water Pipes has become a serious matter in San Francisco, California, according to the Chronicle of that city. A 30-inch pipe belonging to the Spring Valley Water Company has been repaired so often of late that a number of measurements have been made of the electrical conditions about it. It is stated that at one point the difference in potential between the pipe and the neighboring rails of an electric road was 16 volts, and that the current amounted to 116 amperes.

BOSTON, MASSACHUSETTS

(Engineering News, June 21, 1894, Page 518)

DESTRUCTIVE ACTION OF ELECTRIC CURRENTS ON WATER PIPE

The above paper was contributed by Messrs. Chas. A. Stone and Howard C. Forbes and read by the latter. So much attention has lately been given to electrolytic action that premature corrosion of water pipes from any cause is likely to be attributed to electricity. Ordinary rusting does not take place at a uniform rate, varying, for instance, with the character of the soil, but often natural corrosion is hastened by the action of electric currents.

Experiments are now being made by the authors, at the request of Mr. Wm. Jackson, Am. Soc. C. E., City Engineer of Boston, to find a method of distinguishing between electrolytic and natural corrosion. The various methods proposed to prevent electrolysis may be classed under three heads as follows: (1) Complete remedies, such as the double trolley and storage battery systems, complete insulation of the pipes and possibly the alternating system. For the present the first three systems are considered as in themselves impracticable and it is yet too early to pronounce upon the latter. (2) Partial remedies, such as very heavy return wires from the tracks to the power station, with good bonds between the rails; also returns from sections of track every 500 feet along the route; but this can never entirely do away with the difficulty; the three-wire system, regarding which little is actually known and which is not as yet promising; insulation of tracks, which, as indicated, only tends to reduce the injury. (3) Schemes which are useless as connections from the tracks to the pipes, bringing the pipes to uniform potential and reversing the current at frequent intervals.

In addition to the above methods the connection of the pipes to the negative plate at the power station has been tried several times and with beneficial results. The problem here is to get the current through the joints in the pipe without injuring the latter.

At the opening of the discussion of the paper on electrolysis Mr. I. H. Farnham was called upon. He described a simple method of testing for corrosion by electricity, consisting of placing two short pieces of pipe near a pipe in the distributing system, at the suspected point and connecting one of the pieces with the main pipe. If corrosion was afterward shown in the connected pipe but not in the unconnected the conclusion is obvious. If pipes could be made to carry current without a change in the resistance caused by poor joints, etc., it would be possible by making proper connections with the water mains near the power station to prevent corrosion.

In most cities, Mr. Farnham stated, the trolley wire is positive and the danger district is then near the power station and the current can be conducted to the station by wiring. With a negative trolley wire the danger district would be at the extreme end of the railway. Copper bands can be used to diminish the resistance at poor joints.

Mr. Geo. E. Winslow thought that the storage battery system was less likely to give trouble than the double trolley.

BREWER, MAINE

(Engineering News, June 21, 1894, Page 518)

DESTRUCTIVE ACTION OF ELECTRIC CURRENTS ON WATER PIPE

Mr. Sparks said that in 1890 a 12-inch main was laid from a pumping station at Veazie, Maine, across the river to Brewer. Water and electric railway plants were run by the same company and the return was made by connecting with hydrants. After a few months of use, the submerged main broke in 35 feet of water. It was repaired, but broke again after a few months, and later still again. The broken pipe was so badly decayed that a ring nearly around it could easily be broken out with a hammer. A new main was laid and about the same time seven strands of No. 6 copper wire were carried beneath the river and connected with the pipe at each end. Since this was done there has been no trouble.

EARLY ELECTROLYSIS REFERENCES

(Engineering Index, Vol. II, 1892-1895)

Page

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MADISON, WISCONSIN

(The Electrical World, August 18, 1894, Vol. XXIV, No. 7, Page 144)

ELECTROLYTIC CORROSION OF IRON PIPES

An interesting paper recently read by Prof. D. C. Jackson before the Western Society of Engineers takes up the question of the corrosion of iron pipes by the action of electric railway currents and the conclusions arrived at are of considerable practical interest. Prof. Jackson expresses the opinion that with a perfect return system properly connected to underground pipes electrolytic disturbances may be made to practically disappear. In order to determine as exactly as possible what occurs in the soil due to the return current a series of laboratory experiments were performed in which the practical conditions were reproduced as nearly as possible. As the result of many experiments he concluded that in no case is the action due to the electrolysis of water, and where oxygen is liberated at the anode, it does not attack the iron; that only a mere directive force in the nature of a pressure will cause electrolysis; that the actual corrosion is therefore only dependent upon the actual current which flows, and is as much dependent upon the resistance of the soil as upon the pressure tending to cause the current; that only a minute quantity of soluble salt is sufficient to start the action, and it will then continue as long as a current flows; and that the gravity of a corrosion of a pipe depends on the amount of current flowing from a given area and the nature of the salts present in the soil, the order of the activity of the salts being (1) chlorides (2) nitrates, (3) sulphates. The statement that there is no evidence of direct electrolysis of iron, but that corrosion is the result of electrolysis of chemical compounds which are held in the water of the soil, setting up secondary chemical reactions, seems to explain the enigma of electrolysis with exceedingly small E. M. F's, but a quantitative demonstration of this process would be of much interest. It would appear that the difficulties to be overcome in order to get rid of corrosion are not so great as generally supposed, though success depends much upon a special study of the conditions of each case. In Madison it required an expenditure of only $8,000 to do entirely away with all trouble, and this would have probably been considerably less if proper precautions had been taken when the track was first put down. It remains for time to prove, however, the durability of the numerous connections necessary to be made, but this is a minor problem and of little moment compared with the one whose solution involves it.

MEMPHIS, TENNESSEE

(The Engineering Record, September 1, 1894, Page 219)

ELECTROLYSIS AT MEMPHIS, TENN.

In a paper before the American Water Works Association's convention at Minneapolis, Mr. A. A. Tucker gives an account of the experience of the Artesian Water Company, of Memphis, Tenn., with electrolysis. Soon after the street railways of Memphis substituted electric for mule motors in 1891, numerous leaks occurred in the services along the line, and the pipes removed had the pitted appearance produced by electric corrosion. Although the railway company has never admitted that stray current from their lines may have had anything to do with the damage to the pipes, it has been improving its track circuit in several ways.

One of these consisted in using a lot of old rails as returns. These were run out from the powerhouse along the bayous and bonded with 00 copper wire. At points where the railway crossed the bayous on bridges the track rails were connected to the returns by 00 copper wire. Mr. Tucker states that from what the Superintendent of the railway company has said, about $600 in coal was saved the first month these returns were made; that is to say, electricity to that value had been prevented from frittering itself away in getting back to the powerhouse.

The railway company has also taken out its old iron bonds and substituted short ones of 0 copper wire. A 6-inch special service main about 1,000 feet long runs to the powerhouse, and this is connected at two points with the negative side of the generator by an 0 copper wire wrapped around the pipe four or five times. At the time these connections were made a voltmeter test showed from 6 to 15 volts difference of potential between the pipe and the conductors to the generator. At another point about 1,000 feet distant another connection was made, although in a different manner. The 6-inch main at this point was tapped just outside the track and a 2-inch plug inserted in the hole. Two holes 1 inch deep were drilled into this plug and a 0000 copper wire soldered into each. One wire was connected to the nearest rail and the other to a 0000 copper overhead return wire. A similar bond was made 400 feet further along.

These connections were all made during the present year, but the damage still goes on. In a very short time after the last one was made a leak occurred about 200 feet away, over a 16-inch main parallel with the track. On digging down it was found to be in a 6-inch castɔn plug in the west end of a cross pointing toward the track and ·out 12 feet from it. Since this leak was discovered many others ve occurred in service pipes along the line, and consequently Mr. ıcker has little faith in the value of the preventive measures underken.

EPORTS TO ANNUAL CONVENTION OF AMERICAN WATER WORKS ASSOCIATION

Year 1894

By A. A. Tucker, Memphis, Tenn.

Mr. Willis Chipman of Toronto, Canada, was on the program r a paper on "Private Water Companies, Province of Ontario," but e paper was not presented. The secretary then read the paper on ;lectrolysis; Experience and Opinions," by A. A. Tucker, Memphis, ːnn. The consideration of this paper was deferred until the general bject of electrolysis should be under discussion.

ELECTROLYSIS—EXPERIENCE AND OPINIONS

The secretary of our association requested that each member conibute a paper on some subject of his own individual selection. I have lected the one at the head of this paper, and I have done so feeling y inability to enlighten this intelligent body on this mysterious and ımaging element, "electrolysis," to underground water pipes.

I shall content myself with giving some of my experience along is line, and, while I do not expect to instruct, I trust what few words say may interest, at least, some members of this intelligent body.

I find that electrolysis is not a new element, but dates back to es past, and only of recent years has it appeared, in the phase of destructive element to underground water pipes, but it is now one if not the most important matter coming before this body.

In 1891 the system of street railway in our city was changed ›m animal to electric power, and in the course of a few months ereafter numerous leaks in service pipes began to develop along and der the tracks at various points in the city, and especially along the e between the car shed and the powerhouse, which are located about one mile apart. I grew suspicious and my opinion was that electricity was responsible for these numerous leaks. I began in a limited way an investigation. I instructed my repair force to bring to the office samples of all pipes as taken out, and I noticed that these samples were all affected in very much the same way, being pitted and eaten out in round holes, very much different to any pipes that I had ever noticed before.

After pursuing this course for a while and satisfying my own mind, I brought the matter before the president of our company, and he laid the matter before the board of directors, but they, not being electricians, could not understand how electricity could affect these pipes, and treated the matter, I might say, indifferently, coming to the conclusion that I was "barking up the wrong tree," and as far as they were concerned the matter was dropped. I not being an electrician, or the son of one, had nothing more than my opinion to sustain me. However, I still had an opinion, and kept gathering samples and tagging them and putting them away.

At our twelfth annual convention, held in New York in 1892, I brought some of these samples with me, and while I did not exhibit them to the convention as a body, I showed them to quite a number of the members of the association, but I failed to get an expression from any of them as to the cause of the condition of these pipes. My next step was to write an article to "Fire and Water," giving an account of my trouble, and calling on my water works brethren to know if any of them were having like trouble, as up to this time I had heard of nothing of this kind elsewhere. My article was published, and an editorial comment of some length followed. I received several replies to my article through the same medium, and several written communications detailing trouble of the same nature in other places. I opened up quite a correspondence on the subject, and after accumulating this correspondence I again brought the matter before the president, and handed him all of this data to sustain me in my opinion. He again brought the matter before the board of directors, and they then, with all this data before them, concluded that I had "struck a trail." Then a conference with the railway company was the next thing sought, but as they seemed to be indifferent a conference could not be obtained for some time.

At this juncture I began to send the railway company bills for all repairs made on pipes that were affected as described above, and while they have not paid any of these bills, they now seem to be taking some steps to relieve the situation, although they have never manifested the interest the case demanded, and neither will they admit that "electrolysis" is responsible for the damage. In this they may be wise, as no one can tell as to the extent the damages may reach. Thus far the known damages in our city have not been very large, and have been confined to service pipes, except in two instances; one where a six-inch main was burned out under the track, and a six-inch plug in the other instance.

What has and is being done to remedy the matter?

First. The railway company had quite a lot of old rails on hand, and these they used by starting out from the powerhouse and running this rail up along the bayou or bayous, as several of these natural water drains traverse our city, bonding these rails with 00 copper wire, and connecting same with the road rails by means of a 00 copper wire under the bridges at various places throughout the city. Whether this was done to benefit the water company or the railway company I am not able to state; but I am constrained to believe that it is beneficial to our company, and from what the superintendent of the railway company told me, it certainly proved very beneficial to his company, as he said he made a saving of $600 in his coal bill the first month after this was done.

Second. The railway company are taking out the old iron wire bonds and substituting them with larger and shorter copper wire bonds, although in my opinion this copper wire is entirely too small, it being only 0 wire. And, again, as the railway company desired a water supply at their powerhouse, and our nearest main thereto being 900 or 1,000 feet, a six-inch main was laid to their powerhouse, and to this main the water company allowed them to connect by means of copper bands, formed by wrapping 0 copper wire around the pipe some four or five times. One of these connections was made just outside the powerhouse in front of a four-inch meter. The other connection was made about 100 feet north of this, at which point the railroad track terminates. Both of these connections were connected on to sixteen 0 copper wires running to the negative side of the generator. A volt meter was applied to the pipe at the time these connections were made, and showed that our pipe was conveying from six to fifteen volts, about power enough, I am informed, to run a sewing machine, and yet electricians tell us that one or two volts will affect water pipe.

A little later, at a distance eight hundred feet north and four hundred feet west of the last named connection, at a point where a six-inch main was burned out crossing under the track, another connection was made, but differs somewhat from the one just mentioned, as it was made in this way: we tapped the six-inch main just outside the track and put in a two-inch copper plug, which had two holes drilled down into it to the depth of one inch. Into these holes two 0000 copper wires were inserted and soldered, and one of these wires was connected to the rail and the other one to a 0000 copper overhead return wire. Still four hundred feet west of this connection another one was made similar in every respect to the one just described. All of these connections were made and allowed as an experiment and after the superintendent of the railway company had stated that he would be responsible for any damage that might occur after they were made. These connections were all made during this year, and still the damage goes on. In a very short while after the last one was made, a leak developed at a point some two hundred feet north of this, over a sixteen-inch main running parallel with the track, and on digging down it was found to be in a six-inch cast iron plug in the west end of a cross pointing toward the track, being twelve feet therefrom. This plug showed unmistakable signs of electrolysis. It may have been partially burned through at the time the connection was made, but I am inclined to think not, from the fact that even since then other leaks have developed in service pipes along this line. I have very little faith in these connections. I believe they are beneficial should the electricity leave the pipes where these metallic connections are made, but it is such a mysterious element, and one that seemingly acts so very differently under the same conditions, that we have no assurance that it will not leave the pipes at points between these metallic connections, and I believe it is a well settled fact among electricians that only where it leaves the pipes does damage occur. In my opinion the railway companies are the ones that should seek and apply the demedy for this trouble. It occurs to me that they should take care of this leakage and not allow it to get on the water pipes. The water companies have to take care of any leakage in their mains from any and all causes, and should they allow water to leak, and by neglect or otherwise fail to repair it and it should damage the railroad tracks, the railroads would not seek a remedy, but would jump on the water company.

The railways certainly have no right to use the streets of cities to the detriment and damage of other companies who use the streets in common with them. But the water companies are the sufferers, and of course they cannot afford to sit idly by and take no steps to overcome this trouble. I am of the opinion that this trouble will be overcome, and that, too, at no very distant day. It is of such vast importance, and so widespread throughout our cities, that it is awaking such interest that some method will be found by which the trouble will be overcome. Furthermore, I am of the opinion that if street railway companies would not use so much economy in the use of wire, but use larger wire for bonding, and have a large wire for the return current (either underground or overhead), with rails connected thereto every hundred feet, that the trouble would even in that event be largely overcome. However, this is opinion only.

I anticipate getting some valuable information on this subject from the report of the intelligent committee appointed to investigate the matter at our last "Annual Convention."

Respectfully submitted,

A. A. TUCKER.

Memphis, Tenn., August 1, 1894.

The paper by Mr. C. Monjeau on "Electrolysis versus Water Works Systems," was read and on motion placed on file.

ELECTROLYSIS VERSUS WATER WORKS SYSTEMS

Mr. President and Gentlemen—"Electrolysis," a lately introduced factor in our field of industry, appears in direct conflict with all of our best established methods of construction and operation, and is proving the most stubborn obstacle thus far thrown athwart our path toward financial success and requisite safety and satisfaction to our patrons. Why it is called "Electrolysis," which is a name as inaccurate as insignificant of the thing aimed to define, seems not to be known. We all, however, have a more or less definite idea of what it is intended to convey. (Should any of you need "more light" upon what this inaccurately applied name is intended to convey, let me refer you to Mr. Peter Milne's instructive paper found on pages 153, etc., of last year's proceedings.) Without mounting the stilts of polytechnic schools and universities any more than absolutely necessary as to electrolysis, we may at once consider facts and effects of its undoubted production, and try to get at a view of the core—the force in action, so to speak—of this dangerous and troublesome obstacle.

The effective and, to no inconsiderable extent, the profitable existence of water works systems in many cities is threatened by this agent, which is a direct result of more or less costly waste on the part of street railways using electricity as motive power. Hence, in the sense the word insidious is used in medical parlance, it can truly be said that in electrolysis, or rather wasted dynamo-electric power, we have to hunt and silence the most insidious and rapid destroyer ever known to our craft. And if we consider the hidden effects of this agent in connection with the fighting of large fires, of fires in high structures, or fires dispersed in several wards or parts of wards, and to be fought simultaneously, or all such as to be met at one and the same time (a thing which is not alone imaginable, but likely to occur only too often), it may be appreciated that owners of water works are exposed to enormous responsibility by this destructive waste on the part of electrical railway operators. The prospect of finding a large water works system perforated in a dozen or more places at once, or corroded so thin at as many points as to burst in the raising of pressure from normal to fire or extra fire, is by no means inconceivable. This alone is, or should be, enough to make water companies think very seriously of electrolytic effects. The same is true of cities, towns and villages. Capital is exceedingly sensitive. Let it but appreciate such dangers, and how shall cities, towns, villages and companies locate or sell water works bonds? Who of us would take even a hundred dollars worth of bonds thus conditioned? Many cognate points will suggest themselves in this connection without taking space to name them.

Already large sections of cities are exposed to fire and other no less grave dangers by electrolyzed pipes. Fortunately, so far no very great disasters have resulted that we know of as such. But the insidious work is going on. We are conscious that corrosion is not alone in progress, but is greatly accelerated by electrolytic action. We are not here to assume that all breaks in water systems are due to that subtle agent. We have lived too long for that. Pipes perforated by electrolysis arising from the wasted electric power of street railways are recognizable. There need be no mistake as to that. The obstacle is clearly before us, and must be removed; for, as President Donohue stated at Milwaukee last year, the only thing worse than electrolysis in a water works system is impure water—water that may bring disease and death to innocent consumers.

Several electricians have made experiments of late that are of value to us in considering the subject in hand. The results obtained by each do not widely differ. Those of Mr. Isaiah H. Farnham, of Boston, Mass., most nearly correspond with the results of my own experience and observation. I will here make use mainly of his results in preference to mine and others, because I consider Mr. Farnham one of the closest observers in his profession.

It has been experimentally determined that the potential at which corrosion may go on between two iron plates can be at least as low as .001 of a volt. Until quite recently it was boldly asserted and believed by most of scientific men that a far more considerable current was required to effect and accelerate corrosion. Now we know that so insignificant a potential as .001 of a volt, and likely less, cannot help effect damage at as many points as it thrills water systems. As before intimated, experiments have been sufficiently numerous, and all have resulted substantially alike as far as they concern our cause. In every case a ferrous salt was formed at the anode, or positive pole, and hydroxide of the alkaline metal at the cathode, and thus has been clearly revealed the cause of unusually rapid corrosion in water pipes lying from one-hundredth of an inch to one mile or more from the rails of a railway whose motive power is electricity improperly insulated. The chief aim in experimenting was to learn exactly what takes place in an electric cell under conditions parallel to those met with in practice, and, as may be seen, a goodly step forward has been taken.

Both directly and incidentally it has also been established:

1. That the amount of electrolysis varies with the strength of the current, and that the stronger the current the more rapid the corrosion.

2. That some soils are more conducive of electrolytical action upon water pipes than others.

3. That a current will and does divide between the rail and the moist earth, despite copper wire and other connections and conductors thus far applied; and

4. That in experiments, where no sign of corrosion of pipe metal exists before electricity is applied, by the application of the electric current ferrous salt begins to form at the anode and to extend toward the cathode, and the hydroxide of the alkaline metal, on the other hand, begins to form at the cathode and spread toward the anode, and that where the two meet, a stratum of ferrugenous hydroxide is precipitated.

These several facts, freely acknowledged to be such by the leading professors and practitioners in electro-dynamics, place us in position to distinctly and fairly locate causes of electrolytical damage done to water works systems, and to fix precisely the responsibility for damages which may, and likely must, result in serious loss if remedial agents, or more practically scientific construction, be not speedily substituted for such appliances as most street electrical railways now use.

It is idle to argue or even to attempt to think that the effect of corrosion, generated and accelerated by electricity, can be merely local and not general. Any one who has gained the least practical knowledge of the effects of the electric fluid knows that no member of any integral body, animate or inanimate, can be electrified without affecting the entire body. We have to do here with a force whose motion is but a trifle less rapid and far more subtle than solar light. If the gentle click of the instrument at Heart's Content is instantly repeated on Britain's shore, through a distance of two and a half thousand miles and the influence of the weight and sway of the enormous forces spent on and under the sea, it would be sheer madness to imagine that a potential of a mere half volt will not thrill or shock more or less firmly the whole of the integral water works system of the largest city on this globe.

This simple fact forces to the front a legion of worrisome thoughts, for the water works constructor and operator alike. As yet, iron seems the only metal that can be safely and profitably made into water pipes. Iron pipes filled with cold water will sweat. Sweating they moisten and even wet the earth around them. Wet earth is a very free conductor of electricity. Wet iron is a better one still. And a pipe full of coursing water will divide the current with a wire of the best beaten copper of equal cross-section with such pipe, if such pipe is lying within fifty feet in wet earth.

Even with but these few facts of many that confront us, how will and how can our dear friend, the Samson so warmly cuddled in the lap of that Delilah by the lake—that opulent beauty who t[illegible]ted the power of her swayful charms on so many of your hearts but a short year ago—how, I ask—can our Samson extricate himself with even one fibre of his flowing locks, when his very hydrants are wired and bonded to the rails of a single trolley railway line that covers miles upon miles of the streets under which lie the many branches of his works, and when a positive current at its source strikes an increasing main through which an electric shock, either from a "crazy" dynamo or one imperfectly insulated, may stun or maim a thousand consumers in an instant, or paralyze a fire brigade in the discharge of its responsible duty.

To the foregoing important facts established as stated by experiment, or practice, or both, is to be added another by no means less important. It is that electrolytical corrosion varies directly with the strength of the current, so that any of you can soon learn to estimate how soon you will have to replace a given line of mains or a street or streets of services under given conditions, for the amount of corrosion in a given time depends upon the potency of the current and somewhat upon the nature of the salts in the earth surrounding the pipe.

Mr. C. G. Armstrong, of Madison, Wisconsin, acknowledges frankly that "whenever we have a flow of current through the earth, owing to its irregular conductivity, we are bound to have differences in potential, and where we have differences in potential, electrolysis and chemical decomposition will occur." So far, I fully agree with him, as also with his idea that "oxygen, in its nascent state * * * is the most destructive agent produced by electrolysis," but I cannot yet convince myself that the electrolysis of water is a possible thing—though I admit that an electric current of about two or more volts will dissolve water into its component gases and leave oxygen free to act.

By the way, Prof. Jackson, of the same city, made experiments which forcibly suggest that too many water pipes are placed too near the gas pipes, and thus exposed to the effects of ammonia and "other destructive products of the gas retort, which within themselves, are sufficient to attack and decompose any metal they come in contact with."

Here perhaps it should be inquired whether jarring, which results in excessively rapid vibrations, in the case of electrical railways, does not play quite a part in accelerating corrosion in water works systems. I am satisfied that it does in the case of steam railways, when powerful locomotives and heavy trains more or less jar the earth and electrify it in proportion to their rapidity of motion. And it occurs to me as quite probable that electricity-speeded cars must be at least as likely to shake the earth and, consequently, the water pipes adjacent to rails (for it announces its presence in almost infinitesimally short vibrations), and that from this may arise much of the destructiveness known to result from electrolysis.

The following valuable suggestion I extracted from the criticisms of Mr. A. C. Kennelly on the paper of Mr. Farnham, read at the eighty-sixth or last meeting of the American Institute of Electrical Engineers. It points a moral and may adorn a few brows with—

other lines than such as wreathed the countenance of proud Antony when he first beheld the "fair Cleopatra." Said Mr. Kennelly, "while all admit that * * * iron pipes are corroded electrolytically, and the evidence has been amply brought forward tonight, I do not think that Mr. Farnham means that as much corrosion takes place with iron as with lead, for the reason that we all know a given weight of lead is much more readily consumed by electrolysis than a given weight of iron. Roughly, an ampere in a year will dissolve 75 pounds of lead by electrolysis. It will dissolve, roughly, only about 20 pounds of iron, or nearly four times less."

This incidental but plain evidence bearing on the subject in hand, it will be noticed, is frank, free, full and as irrefutable as unguarded. It is openly avowed to consist of facts well known to all members of the craft to which the witness was addressing his remarks. Nothing can be more positive, and every one can draw his own conclusions. Certain it is that the danger to some water works systems arising from electrolysis, as evinced by this and other facts already stated, must be very great. Much depends, it should be observed, on their relative exposure or relation to a neighboring system of electrical railway. With a relative exposure, such as obtains at Milwaukee, the danger seems what may be termed medium. With the powerhouse of a road near the base of a water system, it seems that all present and prospective dangers appear likely to be intensified where the single trolley is used and a current of say 500 amperes and upwards is applied as motive power. Railways using the double trolley waste relatively very little electricity in the destruction of water pipes. When properly insulated the double trolley wastes next to none at all.

It seems advisable here to glance into electrolytic effects from the standpoint of comparative philosophy.

From close, persistent observation, it appears to me that the effect of electricity on water pipes in the ground, filled with that liquid coursing under pressure, is very similar to that which results among full arteries, veins, and bones of living animal bodies of high orders; and I am convinced that our most useful lessons in the mastery and safe control of electricity must come from that source.

An electric current of a given voltage judiciously applied to a human body ailing from a certain disease usually results beneficially by accelerating a needed degree of destruction of spent and inactive nerve tissue accumulated in excess by reason of indolence, illness, or lack of proper personal care; whereas a greater voltage must result in injury to active tissue and blood; and a greater still in the destruction of life itself. But either in the human or the water works system, a persistently applied electric current, however slight, very soon becomes injurious, because all life and all existences seem to need rest for recuperation from wasteful excitement of the nerve fibres and nerve vesicles, which, after every vibration, have to recharge with effective life force and readjust their living molecules and granules of gray matter by means of the coursing life-full blood. The nerves, like the sponges fixed to their native rocks, have only a relative motion. And as the sponges are bathed with and feed on their surrounding medium whilst it ebbs and flows, so the nerves and their constituents are bathed by and feed upon the blood pumped through and through them by a process not unsimilar to that by which the waters of seas and streams are urged on their life-awakening and body-building effect. Now, passive existences, such as iron and lead pipes, have not that life power to readjust their molecules and granules, nor the life-full blood to bathe and nourish them afresh after every passive effort at resisting outward or inward attacks. Their mode of resting and recuperating, so to speak, is through immobility, or, as in many instances, by moderating of their usual activity, as is the case with the animal heart's action.

Molecules and granules constituting iron and lead pipes kept constantly in active motion (which naturally exposes them to more rapid corrosion) have no rest for recuperation from that degree of strain and wear they are made to stand. Consequently they wear and corrode more rapidly. Now, when a more or less constant current of electricity is dashed through these granules and molecules, additional expansion or pressure duty is laid upon them as a whole and in particular that operates upon them as does the straining of given nerves and muscles in the animal body. And as there is so much heat to a given amount of any fuel, so there is a fixed amount of life force or durability, or usefulness, in all aggregates of molecules, granules, and all bodies whatsoever. And, again, as a man of temperate habits, all things equal, lives longer than one of contrary ways, so pipes and their constituent molecules and granules endure in proportion as they are used. Here may be appropriately repeated a fact which electrical railway engineers of fair intelligence and honesty must and will admit, viz., that the amount of electrolysis varies with the strength of the current, and that the stronger the current the more rapid the corrosion.

I trust all the facts stated make it as plain to you, as to me, why a length of cast-iron pipe can last under average service and fire pressure forty-five (45) years in Petersburg, Va., 60 years in New York City, and 65 years in Boston, Mass., under old-fashioned street beds, whilst in Brooklyn, N. Y., as Prof. George W. Plympton informs us, a pipe of similar size and form, placed "very near the rail" of an electrical railway as substitute for a "pipe that had been destroyed in three to four months (by electrolysis), was perforated in thirty (30) days."

Briefly, upon as careful and practical comparative analysis as the nature of the two sciences involved will admit, and the relative infancy of electrical science now affords, I find that there must exist far less difference than has been hitherto assumed as between what may for convenience be termed the habits or modes of expression of dynamo-electric currents (positive and negative) and such currents as jar, permeate, warm, expand and displace the molecules and granules of quivering gray matter that cluster around the efferent and afferent nerves in the human body, and in thus doing give rise to what we know as impressions, sensations and feelings. Hence, I am the more confident that the foregoing conclusions as to electrolytic corrosion or disintegration of water pipes cannot seriously misguide any member of this association. And hence largely also, is my firm conviction that the return of negative dynamo-electric currents must prove relatively as destructive to water systems as the positive, popular belief to the contrary notwithstanding.

Now, I frankly acknowledge that I can conceive of certain soils in which a gentle flow of electricity along water pipes might have a tendency to prevent natural corrosion rendered unusually active by the presence of certain chemical properties of such soils. But I cannot bring myself to believe that a dynamo-electric current in a water works system constructed under average conditions can result in anything else than unwarrantable damage. The doctrine of Sir William Hamilton, that pleasure is a reflex of the spontaneous and unimpeded exertion of a power of whose energy we are conscious, appears a safe one for us to make our own under existing circumstances. We have power in the nature of rights—national, moral, legal, social, property rights. And we have a duty. It is to keep conscious of the exertion of the power inherent in these rights to locate known damage done where it belongs, and publicly and legally fix dangers now spreading and deepening with every turn of every dynamo's flywheel in every powerhouse of every railway in every city of our broad jurisdiction.

I grant that the world's knowledge of electricity is comparatively narrow. And I freely confess to knowing no more about electricity than I do about water, which I find a profound mystery consisting of innumerable mysteries which deepen and broaden into infiniteness with every successive year of studious research I spend upon them. But there is more knowledge of electricity and its habits and effects than is practically applied in the vast majority of cases where damage and danger to water works systems in cities are daily and nightly increasing. We have within our Union and Canada at least a score of electrical and other engineers who can devise, construct and operate electrical railway systems with far greater safety to all concerned than any now existing. Why they are not employed may readily be inferred. Hence, it seems time for members of this association and their patrons to call a halt. When capital gets so greedy, and its possessors so mercilessly selfish as to most unjustly and heedlessly expose the public health, person and property of others to destruction for the sake of greater dividends, then, under a government of the people, by the people and for the people, no man worthy the name of man and American has any longer either the right or the liberty to remain silent, or to withhold his best efforts from the needs of justice and public health and safety. For such ruthless heedlessness of others' rights and comforts is the very worst type of Debsism, and justly deserves such attention as the French Republic has paid to the butcher of her martyred President.

Perhaps a kindred subject not coming exactly under the title of this paper should be here stated because of its general interest.

It is pretty generally believed that the running of an electric current through a system of water pipes in active service is of much benefit. The notion originated years ago in the speculations of a German "specialist," who was attempting to increase human longevity by disinfecting rivers, reservoirs of drinking water and sewers by passing through them a strong electric current. It was a novel and attractive idea. Our public press, always ready to dress new ideas in the most attractive Yankee style, so artistically embellished that erratic fancy that even P. T. Barnum, the creator of the "Great American What-is-it," lost his genial temper at Horace Greeley and other mighty New York editors because, to use the inimitable showman's own style of phrasing, they couldn't "give the d—d thing a shape he might buy and put in his show." I hailed the novelty hopefully, and even with enthusiasm. But upon experiment it proved worse than useless. An electrical current potential enough to kill (or reverse life in) every living creature and animal and vegetable germ perceived in water very likely destroys billions more that are not perceived, and which seem to constitute essential parts of good, thirst-quenching, nutritious water. Briefly, I found, much to my surprise and regret, that if you give a running open stream a strong electric shock you destroy in its water what seem to be essentials toward quenching thirst and supporting life. The dead matter (except the fish) speedily decays and sinks. And thus deprived of many natural components, such water perceptibly fails to enliven vegetation as ordinary stream or ground water in its natural state usually does.

I never tried the experiment in a water works system, but it seems to me safe to infer that kindred results must follow in that. Of course, were such a system shocked, it would soon mainly clean itself of dead matter in favor of the consumers. But can you not imagine what rich reservoirs of liquid putrefaction the "dead ends" would become? Yet who of you, managing water works systems, and having the wasted electricity of railway lines toying with your pipes as it must, can say that germs of such disgraceful and dangerous diseases as typhoid, diphtheria, cholera morbus, etc., are not developed from their previous states and liberally bred in just such dead ends?

This seems to be an element which should by no means be left out of consideration in summing up and fixing the liabilities of electrical railway companies who, for reasons best known to themselves, fail to apply the care, knowledge and precaution requisite to public safety, and property generally, in constructing and operating their lines.

Judging from the depth of interest evolved during last year's meeting by discussion of the dangers to water works resulting from electrolysis, it is inferred that a brief consideration of remedial means for such dangers would not be out of place here.

It is often asked, "Are there remedies for this destruction resulting from electrolysis?"

It can be prevented. That is known and certain. That is precisely what renders the injury inflicted upon us and our patrons inexcusable and exasperating in the extreme.

Electrolysis can be prevented.

1. By using the double trolley suitably insulated; or

2. By the use of suitably fished or bonded rails properly insulated, and what Professor Elihue Thomson terms the employment of potential reducing motor generators at various points over the area covered, the high potential side being fed directly from the power station by metallic circuit, and with either alternating or continuous currents, as found most expedient; while the low potential side, 500 volts or less, would go to trolley, wire and track respectively. In such a case, the return current would never have to travel very far, and the drop on the whole system would be so much lessened as to render a sufficient insulating of the rails no difficult task.

In any case, there should be no connection of dynamos at power stations with the ground. In fact the entire plant should be completely free from ground connection as far as the electric fluid is concerned, else so far as now known there can be no safety to water works and other systems using lead and iron.

Then, on our part, purer lead and purer iron should be used. Impurity in those metals seem to be seldom considered. That is a radical disregard of proper engineering and superintending as of the best interests of all concerned. The more impure the metal the more susceptible it is of corrosion and disintegration by any means.

If you have means convenient I will take pleasure in practically illustrating to you what I mean by what I have read.

The report of the special committee on "Electrolysis Affecting Water Mains and Sewer Pipes" was called for.

Mr. Benzenberg—There were quite a number of questions asked in the discussion of the paper on this subject yesterday afternoon, which might have been answered at that time; but I thought it was better to reserve the discussion until this report was read, and made that suggestion.

The paper was read as follows:

To the Members of the American Water Works Association:

Gentlemen—In submitting what will have to be accepted as a report, the committee on electrolysis as affecting water mains wish to state that none of its members two months ago knew that they had been appointed to act thereon, and for that reason are less prepared to submit a more exhaustive report, and one based rather upon personal investigation and study than upon that of others. The committee has had no opportunity to meet, and the correspondence has of necessity been quite limited.

Since the last meeting of this association, this subject of corrosion and the destruction of water mains, gas and service pipes, cables, and other underground conductors in streets where electricity has been introduced as the railway motive power, has at the hands of the various engineers and the chemist received a much more scrutinizing and scientific consideration, by closer investigation or by experiments and laboratory tests, and thereby much of the mystery which seemed to surround this destructive process some twelve months ago has been removed. The doubt which seemed to exist in the minds of many as to the corrosive action occurring only at such points where the current left the enforced conductor has been entirely removed, and the fact established that only where the pipe or cable is positive to the earth and to some other conductor, and the pipe or cable assumes the position of an anode to that other conductor, be it the rail, some other pipe or cable, or the generator itself as the cathode, with the intervening earth as the electrolyte, that corrosion takes place by electrolytic action. It has also been established in experiment by more than one party that it needs but an extremely low potential, not exceeding one-hundredth of a volt, coupled with other favorable conditions, to produce electrolytic action, though it may take considerable time to cause the results to become apparent.

During this time, also, information has been received from many additional cases where injury to water mains, service pipes, or cables has been reported, the investigation of some of which were placed in the hands of electrical experts or commissions, whose reports thereon have been published from time to time in some of the technical publications.

All of these reports agree with the views held heretofore, that the trouble is caused by the imperfect means provided by the electric street railway companies for the return of the current, and suggest sundry improvements upon the methods employed to return this current, from the double overhead trolley system, or the continuous perfectly insulated underground cable return, to the various methods of bonding the rails, and the use of an ordinary continuous return wire connected with the rails. Of these methods, undoubtedly the first two, while in perfect condition, would afford the most complete protection; but there are sufficient serious objections to them on the part of the street railway companies to prevent their being adopted, and the remedies, therefore, must be sought along the line of more reasonable requirements, and against which the companies cannot sustain valid objections. By this statement it is not meant that it should be inferred that the electric railway companies should not be held to provide for positively adequate means of returning the current to the generator without damage to other property, but that if such object can be accomplished by other more moderate and suitable means, the companies, who are deeply interested in the return of the current at as high a potential as possible, will undoubtedly more readily provide the means of protection.

The rails, which in the first instance receive the return current, unquestionably possess, if the same were continuous without a joint, a sufficient conductivity to return all the current to the generator, excepting what in any case, under the law of divided circuits, is certain to escape to other conductors, if such exist. Therefore, all that is necessary to obtain the most perfect uninsulated and available conductor is to reduce all possible resistance at the rail ends by providing a most perfect bond between them, equal to the rail in conductivity; or, in other words, by rivetting a copper bond of about twelve inches length to the rail ends, the section or number of these bonds to increase as the powerhouse is being approached, supplemented by similar cross bonds, connecting the four rails to each other every 100 to 120 feet.

These rail bonds should in section or number anticipate increase in traffic and extensions.

If a number of railway lines are operated from one powerhouse, and particularly if the same is not on the line of the railway, ample return feeders should radiate out to the various centres, so as to relieve the overloaded rails, and these return feeders should be well insulated, to preserve them, and also to prevent leakages to the ground.

However, even with such careful and most ample provision for the return current through the rails and insulated return feed wires or cables, a certain percentage of the current is, especially in moist earths, bound to leak through it to some other conductor, and the amount thereof will depend upon the combined resistance of the earth and conductor compared to that of the rail or other return circuit.

If this amount does not increase to such an extent as to make this conducting medium, be it water, gas pipe, or cable, at any point, positive to either the rail or any other conducting medium, so as to cause the current to leave it, there would be no harm done, providing the conductivity of the pipe were uniform throughout and made continuous to the generator by an ample and perfect connection at some suitable point.

With a proper bonded rail circuit, reinforced by insulated return wires or cables from central points, such increase of current on any water pipe is not easily possible, as the resistance offered by the water pipe is very low, the metallic section of a 6-inch water pipe being only one and one-half times that of a 70 pound rail, while that of an 8-inch pipe is 2¼ and of a 12-inch pipe 3¾ times as great; therefore, the perfecting of the circuit from the pipe to the generator in such cases is generally sufficient provision to protect the water pipe from electrolytic action.

But in all cases where the resistance to the current in the rails has not been reduced to a minimum, the proportion of the leakage becomes greater and, where the bonding is poor or imperfect, the resistance in the rail circuit becomes so great, as to cause the water pipe to become the main return feeder, if not along the entire line, at least in many sections, and thus the pipe at many points becomes positive to adjacent or parallel conductors, at once establishing conditions which will produce electrolytic action, the strength of the destructiveness of which to the pipe will depend upon the low resistance offered by the earth and upon the amount of soluble salts—the electrolysis of which are injurious to the iron—that are contained therein. These salts, according to extensive experiments made by Prof. D. C. Jackson, of the University of Wisconsin, and reported by him in a paper read before the Western Society of Engineers, consist of chlorides, nitrates, and sulphates, given in the order of the effect of their activity upon the iron pipe when acted upon by the electric current; a mixture of these salts causing intermediate results. These salts in some one form or another are to be found to a greater or lesser extent in almost every street soil, and, as Prof. Jackson has demonstrated, "only a minute quantity of soluble salt is sufficient to start action, and it will then continue as long as a current flows." It is clear, therefore, that the conditions are favorable to the corrosion of the pipe.

Again, quoting from Prof. Jackson's most valuable paper on this subject, he says: "The problem of preventing the destructive electrolytic effects upon the pipes of the railway return current is shown to consist simply of the prevention of electrolysis of the salts of the soil, when the products of electrolysis are of such a nature as to attack iron."

To accomplish this it is but necessary to prevent the pipe at any point from becoming positive to the rail or any other possible conductor. Whether the pipe is positive or not can be easily determined by a few observations with a voltmeter at points radiating out from the powerhouse and along the line, where, by a perceptible difference in the potential between rails, the existence of poor or defective rail bonds is located. The fact and the points where the pipe is positive having been settled, the railway company should not lose a moment to re-establish the proper conditions for the protection of the pipe.

If not already provided, ample and suitable protection by an insulated cable should at once be made between the pipe and the generator to afford the least resistance for the proper escape of the current to its destination. If this has already been supplied or the pipe is still positive, the rail bonds at such points should be perfected and, if the conditions are such that an increase of the section or number of such bonds will not entirely remove the difficulty, proper and suitable metallic connections should be made at such places between the pipe and rail, so as to permit the return of the current to the rail until the proper equilibrium, dependent upon the relative resistance, has been established; without the necessity of passing the current through an electrolyte and of developing electrolytic action in the accomplishment of such result.

Insufficient rail section, inadequate return feeders, or, especially, wet soil, presenting an easy avenue for the current to reach the pipe, may make it necessary to add to the number of such connections, but they should only be made where the pipe is positive in order to relieve the pipe and for no other purposes. If this method is followed no damage, it seems, can arise to the pipe, but, to the contrary, the best possible protection given it against an agent whose permeating power it is impossible entirely to escape.

The only question which may arise in connection herewith is, as to the uniform conductivity of the pipe, whether there is sufficient resistance in the lead joints to cause some of the current to pass around and in doing so produce electrolytic action.

In a measurement made last Thursday at the lead joint of an 8-inch water main in front of the powerhouse of the Milwaukee Street Railway Company, through which main 16 per cent of the entire output of the station (or 421 amperes) is being returned (31 per cent being the entire amount returned through the water mains), a drop of potential of but 0.0198 volt was found to exist between the ends of the pipe, indicating a resistance of 0.000,047 ohm, certainly not sufficient to produce electrolysis even with the most favorable conditions existing at the joint.

But, do any favorable conditions exist?

Professor Jackson by his great number of experiments has established that "in no case is the (corrosive) action due to the electrolysis of water; where oxygen is liberated at the anode, it does not attack the iron," and again: "In order to have the first electrolytic process go on (that is, direct electrolysis of iron) a soluble iron salt must be present in the soil, reaching from anode to cathode. The analysis of street soils shows no such salts."

Corrosion at the joints, therefore, can only be caused by the electrolysis of the soluble salts heretofore mentioned, if they exist between the hub end and the adjoining pipe at the joint. A most careful examination of the pipes and the lead joint in the 8-inch main above referred to, did not show the least perceptible action or corrosion, although the main had been used as a conductor for years, It does not seem, therefore, that there is the least cause for any anxiety that corrosive electrolytic action may take place at the lead joints, and hence, a water main of like diameter may safely be considered to possess a uniform conductivity throughout and capable of conducting without injury, so much of the current as under the law of divided circuits it cannot avoid conveying.

The 8-inch water pipe, where the same is connected by a 500,000 circular mil cable to the generator, was subjected on either side of the connection and in under the clamps to a most careful scrutiny and examination, but notwithstanding the clamp and cable had not been touched for fifteen months, not even the least discernible change could be detected at any point. Where the iron pipe had been filed to form a contact with the clamp, the fine markings of the file were as sharp and distinct as on the day they were made. Other connections between the rails and pipe which were examined were found to be in equally good condition and all possible information obtained so far indicates that all corrosive electrolytic action on or along the pipes has been arrested.

Undoubtedly, electric street railway companies will soon, if they have not already, learn to appreciate the economy stored in a perfect return circuit of least possible resistance, and perfect, by improved copper bonds and return cable feeders, their present in many instances inadequate system.

The line of inquiry and investigation for the water works engineer to pursue and the remedy, if needed, to be demanded at the hands of the railway company has been made clear at least, by the investigations and experiments which have been made; and he can now by his own observations ascertain whether or not any part of his pipe system is endangered.

G. H. BENZENBERG, Chairman.
L. H. GARDNER,
F. A. W. DAVIS,
EDMUND MATHER.

Mr. Benzenberg—I wish to dwell a little more upon how the water works engineer can satisfy himself perfectly whether his pipe is in danger or not, by using a volt ammeter that will record a fiftieth part of a volt or ampere; and that any of his men can, at the time they tap the main along the lines of a street railway, or else occasionally with a hydrant, connect the same, one end with the water pipe and the other with the rail and take a reading. If it indicates that the pipe is positive there is danger to that pipe. If the pipe shows it is negative to the rail, there is no possible danger. The information can be easily and quickly obtained. It does not need an expert. A careful man, a tapper, or any one of the employees, except he be a common laborer, can keep on making these observations and soon ascertain whether any part of the pipe is positive.

As soon as it is found that the pipe is positive to the ground, further investigation should at once be made, whether the soil contains any of the soluble salts heretofore mentioned; and if it does, there is no question but what electrolysis is taking place and corrosion of the pipe is occurring at some point. There is no necessity of opening a trench to ascertain where this electrolysis is taking place; all it needs is to establish the proper equilibrium between the pipe and the rail, where the pipe is found to be positive, by making a connection, with a good clamp and a sufficient copper bond, between the pipe and the rail. At that point at least and for a long distance, the pipe is immediately made negative and freed from all danger. The change takes place quickly. I have known where a tap had been made and the volt meter showed the pipe to be five-tenths of a volt positive (sufficient to produce corrosion if the salts of the earth were of such a nature as to cause electrolytic action), that where a bond was placed around that pipe—keeping the volt ammeter in connection—the moment the connection was made with the rail, the pipe became negative.

I think it is well for the water works engineer to be in possession of this information, and to make these tests for himself. We have not been able to get much information from the electrical engineers of the railways, but that may have been because they were not aware of the true state of things. It was supposed that electrolysis of the iron was taking place, and that the iron was being affected directly by the electric current, but it is really, as shown by the extensive tests and experiments made by Prof. Jackson, caused by the soluble salts of the earth such as chlorides, nitrates or sulphates of ammonia, or potash or soda, which being affected by the electric current, hydrochloric, nitric or sulphuric acid is at once generated, and this acid attacks the iron pipe, eats it up, as it were, causing the pitted appearance where the acid works upon the water pipe. It is the chemical action and not the electrolytic action that is producing these results. The action is secondary upon the pipe, but not primary. The water works engineer should provide himself with this information, and thereby remain master of the situation, instead of being compelled to make inquiries of others. Many have been making inquiries as to whether their pipe is in danger. They feel anxious about it, and go to the electrical engineer of the street railway company, or some other party for information, and then do not know whether they are getting all the facts or not. Possibly it would be detrimental to the street railway company to give the facts, and you may, therefore, not get all the information; but the truth is so easily obtained by this method, that every water works engineer should be in possession of it.

Mr. Gardner—During the session of the committee Mr. Benzenberg told us his experience in Milwaukee in making direct connection between his mains and the rails of the street railway company. I should be glad if he would relate that.

Mr. Benzenberg—I would not advise water works engineers to follow the example by any means. We were driven into it by the situation. I knew nothing at all about electrolysis of water pipe. It came to my notice by the bursting of a main, at midnight, in front of the powerhouse, and by the street being broken up and damage being done to the adjacent property by the flow of water. I was not suspicious at that time as to what was going on. Upon investigation it was found that the street railway company, when it changed its horse line to the electric system, in order to find a convenient return feeder or ground, connected their wires with hydrant or water pipes and service pipes, without asking any questions or saying anything to anybody. It could not be ascertained where these connections were made.

n order to find out where the connections were made it would have een necessary to uncover the pipes and hydrants along the lines of he street railway. I finally compromised. Studying the subject, I hought there would not be any great danger to the water pipe if a uitable egress for that current was provided at the powerhouse, so as ot to force it through the earth. It was agreed, therefore, that they ould make fifty connections to the hydrants at specified locations if hey would remove all other connections. They had something like ne hundred and ten of them. A very perfect bond with the hydrants, nd in some cases with the pipe direct, was made by copper wires, and y providing a clamp around the iron, first removing the coating of he iron. All these places were located, so that if any trouble should ccur, knowing where they were they could be disconnected. Since hen they have been allowed to make additional connections. We ere in a position where we had to do this; I would not, however, dvise it. We are now returning, by measurement made last week, hirty-one per cent of the entire output of the power station back to he generator through the water pipes, and no damage is done. At he very point, opposite the powerhouse, where the entire current was assing through the pipe, the minute ridges made by the file, which as used to remove the coating in order to obtain a good contact with he iron, were found to be just as clear and distinct as they were at he time they were made. That shows that if the current is properly aken care of, it is no great damage to the pipes; but there is no need f getting any more of that current on the pipes than necessary, beause it means necessarily closer watching and examinations. Tests re being constantly made wherever the mains are tapped along the nes of the street railways to ascertain whether the pipe is becoming ositive or not. Occasionally it is found to be positive, and at that oint connections have got to be made. This depends a great deal n how many cars are running over a certain distance, and whether avel, and consequently the current, is being increased on the return ipe circuit, which, not having sufficient connections, then become ositive at that place. If the current is limited to the amount that ill flow through the ground, depending only upon the conditions of he moisture of the earth, etc., and nothing more, there is no trouble n getting rid of it, and there is very little chance of the pipe becomng positive at any point. In Madison, Wis., they had a great deal f current going through the ground, but no electrolytical action was iscovered, because of the absence in the ground of those soluble salts hich by electrolyzing generate acids which attack the iron. For this eason the current may pass through the earth without causing trouble. This is true, I understand, also in the case of Quincy, Illinois. They have had no trouble there. The ground evidently contains no such salts, and the current may safely pass from one end to the other. I think Prof. Jackson has thoroughly demonstrated in his laboratory work that by putting fine moist sand, with none of the salts contained therein, in his cells, and allowing the current to pass from the anode to the cathode, no electrolysis took place, but that as soon as he introduced into this sand any of the salts of chloride of potash or sulphate of soda, or any of those salts, electrolytic action was immediately established. The acids were generated, and immediately began to attack the metal. There is no doubt that the action is a chemical one, induced by the effect of the electricity on these salts.

Mr. Gardner—That pipe you speak of as being in the neighborhood of the powerhouse which burst—that break did not occur from any weakening of the pipe by electrolytic action?

Mr. Benzenberg—Yes, sir; that was the cause. It was all eaten up, and so soft that in pressing the point of an umbrella on the pipe it went through the iron as if it was a sponge. After the metal had been exposed to the air it hardened again. It had been affected and made spongy by the action of the acids. That pipe had been affected that way for perhaps a year before it finally gave way. Before that time there had been a number of lead service pipes, which were connected in the same location, that had been eaten up, samples of which had been brought into my office; but I could not explain what it was until after the second time, when an analysis was made of the soil which surrounded the pipe to ascertain if there was any acid in it. The chemist reported chloride of ammonia in the soil. I had no suspicion it was the electrolytic action which caused all the trouble until after the main burst.

Mr. Gardner—When do you apply this volt meter?

Mr. Benzenberg—At such times as the pipes are uncovered in the regular work. Trenches are not opened for that particular purpose, but as it happens here and there, the observations being made in a few minutes.

Mr. Bond, of Wilmington—I do not know whether the statement made will explain the condition we are laboring under. The electrolysis in our pipe does not appear to be like that of the specimens on the table. It shows a circle increasing in depth, as the circle increases in diameter, until the thickness of the pipe is reached, and then the water forces this plug out and causes a leak. In many places we

ck up a plug that exactly fits a hole in the pipe, from which it came.
a section of six-inch pipe, thirty feet long, we found three of these
les to a foot, ninety holes in the pipe. We come to a soft place, and
taking a hammer and striking the pipe, the plugs would come out,
e the bung of a barrel. We had a length of twelve feet, with thirty-
ree holes of that kind. I do not know why the action should take
ace in that peculiar exactly circular form, and deepening as the cir-
e advances in diameter, just like the crystal of a watch. The plugs
at were blown out were picked up in the ground.

Mr. Cappelen, of Minneapolis—In Minneapolis we have no trou-
e with our water mains, so far, but directly opposite the powerhouse
e were putting in our telegraph wires, police and fire alarm this
mmer, and uncovered some of the old cables to put in the new ones,
d we found the electrolytic action had taken place the whole dis-
nce of the block in that cable, two feet below the surface of the
eet, sixteen feet from the rail. This cable was enclosed in a wooden
x (exhibiting specimens), so that it was not in direct contact with
e earth. We found a difference of potential of five volts opposite
e powerhouse; three hundred feet away, three volts; nine hundred
et away, one volt. We connected up the cable with six strands of
o. 10 soft drawn copper wire, and made a regular stranded wire of
and rivetted it to the rail, and found a difference of one five-hun-
edth part of a volt. I would like to ask how it can be explained,
is cable being in a wooden box, how the action of salts could take
ace.

Mr. Benzenberg—Was the ground moist?

Mr. Cappelen—It was two feet below the surface; sandy soil.

Mr. Benzenberg—There was undoubtedly moisture in the box;
e box was filled with moisture around the pipe. You will find if
u take some of the earth at that point and have it analyzed, you will
scover some of the salts which, when the acid was generated, began
cause the electrolytic action.

Mr. Cappelen—The question was asked if the depth of the pipe
low the surface would have something to do with it. We put our
pes down nine feet, and I examined the pipe opposite the power-
use and could not find any traces of electrolytic action whatever.
also went down in the tunnel, where it is very moist, where we have
r thirty-six-inch main, and which is very close to the powerhouse,
here the underground wires leading from the powerhouse are lo-

cated, and we could not find any traces at all; but in the cable, two feet below the surface, we have the evidence very plain.

Mr. Benzenberg—Undoubtedly the further the water pipe is removed from the rails the greater the resistance, and consequently less amount of current is likely to reach the water pipe. If the return current has been furnished with a good circuit through the rails, only so much of it will likely get into the pipe as will be permitted by the resistance of the earth and of the conductor to the powerhouse compared to the resistance offered throughout the rails. The greater the distance the less amount of current will be likely to reach the pipe.

Mr. Cappellen—The Minneapolis Street Railway Company has used a great deal of seventy-pound rail, and take considerable pains to make good connections, and I suppose that is the reason we have not had much trouble. I have not heard of any trouble with the gas system. This cable which has been shown is near the powerhouse, from which the entire distance of ninety miles is operated.

Mr. Ryle, of Paterson—These samples show a service pipe when it was put it, and in five months that was the result (exhibiting specimen). I got the tongs on here, and it broke there, where it is the thickness of writing paper; that was the second pipe in that place in a year. I cannot account for it. The electrician of the railway company has investigated it, but we could not find out any more about it. This is the lead pipe which was on the block next to the powerhouse. It is the second in a year, and the pitting I find in all of the service pipes I take up; the little circles in this pipe, which Mr. Bond has spoken of in the larger pipe, was done by the water. After the water got through, the sand made a drill of it. It was not the same as in his case, because he said he found the plugs.

Mr. Decker, of Brooklyn—I wish to ask Mr. Benzenberg a question. In making your connection between the pipe and the rail, to change your current from positive to negative, you emphasize the use of the clamp in that connection. What form of clamp do you use?

Mr. Benzenberg—An iron clamp, similar in shape to two half sleeves with flanges is used, to which is connected the copper wire rather than to any tap in the pipe. The main is filed to a smooth surface so that the contact is iron to iron as far as possible, and the wire, say a 000 or a 0000 wire, is wound around the rail or a fishplate, so as to make a thorough connection between the two. In simply winding your wire around the main you do not get a perfect contact.

You want a contact of metal on metal, and for that reason the coating on the pipe is filed down so as to get to the metal.

Mr. Decker—Will you kindly make a sketch of this clamp, to accompany your report?

Mr. Benzenberg—A sketch will be furnished showing the connection between the pipe and the generator at the powerhouse. The other connections are on the same principle, but smaller. I do not like tapping the pipe generally for that purpose, because you have got to make a very close joint in either case and do not obtain as great a metallic surface as with the clamp and because it is more expensive than the clamp.

Mr. Diven—I understand from the report of this committee that the injurious action comes from the electrolytic action of the soil, and that if the pipe and rail are properly connected, so that the current in the pipe is always negative, the injury ceases?

Mr. Benzenberg—Yes, sir.

Mr. Diven—I move that the report be adopted, and spread upon the minutes, and that this committee be continued, with increased powers, such powers to be determined by the executive committee. Carried.

The meeting then adjourned.

POUGHKEEPSIE, NEW YORK

Taken from the Twenty-sixth Annual Report Board of Public Works, Poughkeepsie, N. Y.

1894

ELECTROLYSIS

It having been found, in other cities, that the operation of electric railways on the trolley system, using the rails as part of the circuit had resulted in serious injury to the water mains by electrolysis; and a railway being constructed upon this system in this city, by a company whose franchise contained no provision requiring it to protect the water mains, the superintendent was authorized, in June to seek competent advice as to whether any method of protection could be advantageously adopted by this department.

A communication was, accordingly, addressed by the superintendent, to Isaiah H. Farnham, a well-known electrical engineer, of Boston, Mass., enclosing a map of the city showing the line of the electric railway, describing its general construction, method of bonding, etc., and giving size of water mains along the line and asking advice as follows:

"Are our water mains, or any of them, in such danger from electrolysis as to render it advisable that immediate measures be taken to obviate it?"

"Do you think it advisable that conductors be laid from the dynamos?"

"If so, what should be the kind and size, how far and in what direction should they extend, and how should they be laid and connected?"

"I infer from your papers on the subject, quoted in the Engineering News and elsewhere, that you regard the conductor as the most practical method of protection. If I am mistaken in this please make such recommendation as seems best suited to our case."

In response the following was received from Mr. Farnham:

125 Milk St., Boston, June 30, 1894.

Charles E. Fowler, Esq.,
Supt. Water Works and Sewer Department.

Dear Sir: Your favor of the 25th inst. has been duly received and the situation as set forth, studied. In making reply, I will not deal at length with the laws of electrical currents, the causes of electrolytic action upon pipes, and such questions, presuming you are familiar with the general facts, and will ask explanation if I make statements or offer advice which appears to you in any way questionable, or wanting in clearness.

I mail a copy of a paper on "Destructive Effect of Electrical Currents on Subterranean Metal Pipes" which may assist you in a further study of the subject.

There are two or three facts or laws connected with the use either experimentally or commercially of electricity, that it will be well for you and your associates to have clearly in mind, in order to better appreciate the importance of the recommendations made.

ductor only, when other paths are open to it, but it divides among all paths, the greater amount taking the best path, the least amount the poorest path, and in this proportion through all conductors.

Second. Electric currents always flow from "positive" to "negative" points, or from a higher to a lower potential.

Third. Extremely small currents, even those produced by a difference of potential of 1/100 volt, are sufficient to cause electrolytic action on metal.

Fourth. Electrolytic action takes place where a current flows from metal to moisture, never where the current is in the opposite direction.

CONDITION AT POUGHKEEPSIE

I understand from your description, that the railway being installed is of the usual "single trolley" type, employing the rails as a portion of the electric circuit; that the rails are to be electrically joined or "bonded" with two copper wires, each about 1/3 inch in diameter for the light rails.

You do not say whether there are to be return wires from the rails to the dynamo joining the rails at a few points a half mile or more distant from the powerhouse. Such wires are usual in systems of this size and larger, and I assume there will be three such wires, one west, one north and one east.

You do not say whether there is to be a track wire, i. e., a buried wire following the tracks and joining them at frequent points. Such a wire is frequently used, sometimes instead of regular "bonding" by connecting it to each rail. I assume this will be omitted in your city as the plan for bonding is better than usual where the track is employed.

You do not state which pole of the dynamo will be connected to the trolley system; as the positive pole is generally so connected and as this is the best plan for localizing the electrolytic trouble, I assume this system will be thus arranged.

EXTENT OF TROUBLE TO BE EXPECTED

With the railway conditions as outlined above, I have no hesitation in stating that your pipes in the neighborhood of the power station will be electrolyzed, the extent and rapidity depending on several conditions—number of cars operated, perfection maintained in the track bonds and return wires, moist or dry condition of the earth, location of pipes with reference to rails, etc.

I should expect that within a year from the opening of the road you will find lead service pipes giving out, first near the junction of Main and Smith Streets, then further along in each direction from the powerhouse as far east on Main as White or Mansion; west on Main as far as Garden, possibly Market; north on Smith to Harrison or Thompson.

Where services cross the street beneath the track, and approach it unusually near, the first trouble will occur. The cast iron mains, being comparatively thick and removed to a greater depth from rails will be eaten through less quickly. I should expect trouble with them near the powerhouse within two years.

DESIRABLE PRECAUTIONARY MEASURES

In answering the last portion of your letter, I would remind you that you can do little or nothing independently of the railway company. It must act in conjunction and in harmony with you, which for the most part they may, I judge, be willing to do.

The work of protecting the pipes must be conducted with a design to reach so far as possible these ends.

a. Tracks as nearly insulated from the earth as possible.

b. Tracks and track system as complete and perfect an electric conductor as possible.

c. As little current conveyed to pipes as possible.

d. Such current as finds its way to the pipes, taken off by metal conductor, and not through the medium of surrounding moisture.

RECOMMENDATIONS

a. The bonding, as proposed, is only fair. It would be better if the size of bond wires were substantially increased. They should be attached to the rails in the most substantial manner, having bright metal contact which will not become loosened by the jar or otherwise. All joints of all rails should be bonded.

b. A track wire of No. 000 or 0000 is desirable. If not used, extra precautions at cross-overs and switches should be adopted to insure the permanent continuity of the rail system.

c. Large wire connections, 3 or 4 No. 0000 wires should unite
e rails with rail or ground "buss" bar at the station.

d. Rail return feeder wires, at least one in each general direc-
›n, ought to be empolyed, extending to the centers of traffic; one
r instance, to corner Main and Washington Streets; one to Cot-
ge Street; one to Grand Avenue.

e. No ground plates should be employed at any point; this is
ıportant, and if such plates are anticipated, I desire to explain fur-
er, the objection to them, and the increased danger to the pipes
eir use will entail.

f. No connections should be made between the railway track
stem and water, or any other pipes, except in and very near the
›wer station.

g. The railway company should connect the system "positive"
›le to trolley, "negative" to rails and agree not to reverse this con-
tion without notice to your board and permission from it.

h. It is advisable to extend from the powerhouse, three No. 000
No. 0000 wires, one on Main Street to Market Street; one on Main
› Mansion; one on Smith to Thompson; connecting them at the
ower station to track "buss" bar, and on the street to the water
ain at convenient points along the streets about every 500 feet apart.

The connection may be made by inserting a brass or composition
ug into a service tap and soldering to the plug a branch wire No. 00
tending and soldering it (after winding) to the main wire. The
nnection may be made at the hydrant pipes, if more convenient.
ie wire may be bare copper and placed at any convenient depth. It
ill not be troubled by electrolysis, as the current will be flowing on
it from the surrounding earth. It may be safe to stop this wire
little short of the points named, but with such information as you
ve me, I would advise the wire extended to these distances from
e powerhouse. It is advisable not to connect the pipe return wires
ith the track system, except at the "buss" bar or dynamo.

i. When the road is in operation, and from time to time it is
lvisable to take voltage measurements between the pipes and earth
pipes and rails. If the pipes are found electrically negative, they
e safe; if positive, they should be treated further on the same plan
ıd principle as indicated above.

In conclusion, the positive side of dynamo to trolley, negative to rail, is imperative. If this condition is reversed the pipe return wires will become worse than useless and connections between the dynamo and pipes, as advised, will increase the rapidity of the corroding action, and will transfer it from the neighborhood of the station to all other portions of the city.

Respectfully submitted,

I. H. FARNHAM,
Electrical Engineer.

(Engineering News, September 27, 1894, Page 243)

The method of preventing electrolysis of the water mains at Poughkeepsie, N. Y., is described as follows in a letter to this journal, under date of September 14 by Mr. C. E. Fowler, Superintendent of Water-Works: The street railway company is laying a good track system, fairly well bonded. No ground plates are used and no connections are made between the track and the water mains. The dynamo is connected positive side to the trolley and negative to the rails. By advice of Mr. I. H. Farnham, M. Inst. Elec. E., of Boston, Mass., and also of L. C. Cooley, Ph. D., of Vassar College, this city, the water department is laying a pipe return wire, parallel with the water main, extending about 3,000 feet in each direction from the railway powerhouse. The wire is to be connected with the water main every 500 feet, and also with the negative pole of the dynamos at the powerhouse. The wire is No. 0000 bare copper, laid about 2 feet below the surface of the street. The connecting wires are No. 00 securely joined to an ordinary water tap screwed into the water main. The object is to provide an easy path back to the dynamo for any electricity which may leak to the mains, and thus keep the potential of the main lower than that of the surrounding earth.

ELECTROLYSIS AND ELECTRIC RAILWAY FRANCHISES

(The Engineering Record, September 29, 1894, Page 283)

No one interested in gas or water supply, or in the management of telephone systems, can fail to be impressed with the serious danger to the underground pipes and cables from the electricity passing into the ground from the single trolley street railways. Readers of "The Engineering Record" have been provided with a very full account of all important phases of this matter, as they have appeared in a number of cities, and there are probably many other places which will find electrically corroded pipes in their streets during the coming year. A careful study of such information as is now available indicates very clearly the necessity of much greater care in draughting franchises for electric railways than has been paid to the matter heretofore in the majority of cases, for the injury which a slipshod trolley line may do extends over a greater number of people than the few investors in its securities. Cheap railway construction may involve the working of great injury to valuable water and gas plants and much inconvenience to citizens, and it is very sure that it will entirely prevent the economical operation of the road. Yet that may not disturb promoters who build to sell out instead of maintain and operate.

Proper bonding and the use of ample returns will greatly diminish the loss of electricity from leakage. It is this leakage which corrodes pipes and the lead covering of telephone cables, and both the railway and the owners of the pipes and cables should be interested in checking it. To the railway company it means that as much as 40 to 50 per cent of its current may be going to waste; in other words, half the power station expenses are thrown away. Hence it is not surprising to notice the readiness of the electric railways in most cities where electrolysis has been noticed, to meet the city half way in any reasonable methods of checking the trouble.

To cities and towns contemplating the granting of a franchise, a few words of warning are plainly needed. A good electric railway is a great benefit to most communities, but a cheap affair for speculative purposes should not be allowed. One large New England city some time ago allowed the construction of between 13 and 14 miles of the cheapest kind of track with 48-pound rails, largely along a highway in which the main water conduit of the city is bedded. The fact that this road is capitalized at nearly $28,000 a mile and could be built for half the sum is an indication of its character. The result is that the city engineer is expecting every day to hear that the water main for which the taxpayers have paid is corroded by electrolysis, and owing to lack of proper provisions in the franchise granted the railway, the city will have little chance of making the company pay for the damage done or of preventing its repetition in the future. Other cities have such speculative railways, and the lesson to be learned from all of them is the following:

In granting a franchise for a single trolley road a clause should be inserted binding the railway company to pay to the owners of underground pipes and cables the actual cost of all repairs which may be necessitated by the injurious action of electricity from the railway track on these pipes or cables. Such provision was inserted in the franchises of the electric railways of Brooklyn before electrolysis was heard of, and now that the pipes and cables there are beginning to show signs of corrosion the railway companies are very properly bearing the costs of the repairs they make necessary. Other cities have inserted similar clauses in recent franchises, and the practice is one which ought to be followed in every case. Electrolysis may occur even with well-built roads, yet the probability of its being serious is extremely slight, and if it should occur, the railway company can prevent a repetition of it at a comparatively small expense by methods which have been described in detail in our previous issues.

PHILADELPHIA, PENNSYLVANIA

(Engineering News, October 11, 1894, Page 298)

What to call death resuting from an electric shock is a question which gave rise to a great deal of discussion some time ago. The great authorities seem to have settled on "electrocution," but the daily press reporters have grown more familiar with another electrical term of late since the troubles with gas and water-pipes, due to wandering earth currents, came into prominence. This is probably why the "Philadelphia Press" informed its readers last week that "the instant killing of two large draft horses at Newark, N. J., can only be accounted for by electrolysis."

NEW BEDFORD, MASS., PHILADELPHIA, PENNA., CINCINNATI AND WASHINGTON, D. C.

(Engineering News, October 25, 1894, Pages 338-339)

METHODS OF PREVENTING ELECTROLYSIS OF IRON MAINS

A special committee of the Board of Public Works of New Bedford, Mass., lately visited a number of the large cities of the United States in quest of information regarding the municipal ownership or control of electrical subways. In their report are found the following items respecting the effect of electrolysis on water and gas mains and the methods adopted for preventing it.

Some experts state that the best remedy is to provide an easy passage for the return current, from the water main to the negative terminal in the powerhouse, and say that this can be done by laying a heavy copper wire along the pipe, connected with the pipe by heavy copper rings. Other investigators have lately pointed out that this connection very much increased the amount of current which chooses the water main as a path for its return. This would do little damage were the pipe a good conductor; but, in fact, nearly all lead-calked joints offer some resistance and the current is apt to pass around the joint, and every time it leaves the pipe there will be corrosion.

Another danger coming into prominence is the fact that the current in passing around the joint is more likely to pass inside through the water than outside through the earth. Thus when the current leaves the metal, corrosion takes place on the inside of the pipe. Should the main happen to be a sluggish dead-end, the quality of the water could become more or less affected by the salts of iron or lead deposited.

Philadelphia is trying to prevent these troubles by requiring the street railway companies to conform to very strict specifications relating to the method of laying and bonding the rails, and requires also the laying of extra large return cables, increasing in size as they approach the powerhouse. Several Cincinnati electric railways obviate electrolysis by using two overhead trolley wires. In this way the entire circuit is overhead and through the motors and no current at all goes to the rails. The objectionable features of this system are the cobweb of overhead wires and the additional complexities of operation.

In Washington, D. C., a conduit electric system is in operation, in which an outgoing and a return wire and two trolleys are used. This construction was forced on the company, as Congress refused it permission to erect overhead wires. The system seems to work well. In the case of New Bedford, the committee recommends that all street railways using electricity be required to give bonds to protect the city from any damage by electrolysis, and that they be compelled to use bonded rails and provide ample conductors for the return circuit.

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ELECTROLYSIS OF WATER PIPES

By Mr. C. H. Morse, of Cambridge, Mass.

Mr. President and Gentlemen of the New England Water Works Association:—When my friend, Mr. Nevons, about two years and a half ago came to me in the corridors of the City Hall and said: "Mr. Morse, what effect is the connecting of these wires to our water pipes going to have?" I remember of saying to him at that time: "The effect will be something very slight, I anticipate no trouble from it; you will probably be in your grave before any water pipes are injured by electricity." And then, again, about two months and a half ago, when Mr. Nevons again came to me and said: "Mr. Morse, do you suppose that this electric business is having any effect on our pipes?" and I answered him in an entirely different way, saying, "Most certainly, I haven't the slightest doubt but what it is having an effect," he gave me a look as much as to say, "Why, Mr. Morse! You never think twice alike, do you?" (Laughter.) And it did seem so, really. And I remember he rather brought me to an account for that, and when he said, "You have changed your mind, haven't you?" I gave him some such reply as this: That in electrical matters two years and a half certainly do make ancient history. And I think that is particularly so in regard to the development of the transmission of power by electrical energy. We have had many changes in this department of science within that time. I think I can illustrate it no better than to say that the generators which were developing power for the West End Railway Company two years and a half ago are now obsolete; that the motors which were under the cars two years and a half ago would not be tolerated now by the company; new motors have been placed in service, larger ones, water-proof motors, gearless motors which make less noise, motors which are made dustproof by iron cases; and there are the single reduction motors, the gears of which run in oil, making the operation exceedingly quiet. So I feel justified in saying that the last two years and a half in some departments of electrical work have made ancient history.

Electrolytic action is not a new thing. In the year 1300 note was made of this action. Although the Faradic battery was not discovered till 1799 yet electrolytic action has been known for 500 years at least. Iron tools of miners working in copper mines, were found covered with a thin coating of copper caused by electrolytic action. So you see it is really nothing new which we are discussing today; it is merely a new, accidental application of the subject.

In order that you may understand the whys and the wherefores of this, you will excuse me if I make comparisons and go back a little into the theory of hydraulics and electricity, comparing the flowing of the electric current with the water works system. And this is why it gives me pleasure to speak to men of your business, you will so quickly grasp the situation. I think sometimes when these comparisons are made the speaker does not go quite far enough back. All power emanates, of course, from the sun's heat. We should start from our water works, when we speak about the pressure and fall of potential at the source of supply, the sea. The heat of the sun evaporates the water, taking up only the pure water and leaving the salts, the air becomes saturated with this moisture and it flows back steadily into the interior where it meets colder streams of air, if you please to call them streams, or currents, and condensation takes place. Thus we have our highest potential in a water works system in the cloud. The condensation goes on till the drops of water are formed. The highest part of the water works system is in the cloud. The drops fall to the earth and part of our energy is lost, but the power is not noticed, as it is distributed over such a vast area that the heat effects developed are hardly apparent. The water falls into the water basin and runs back into the store house, as we might call it, the reservoir, and here we generally begin when we compare hydraulics and electricity. Then we have our large mains leading to all parts of our cities and towns, gradually growing smaller and smaller until you get to the faucets in the houses.

Now, if we should derive only power from our water pressure, and use it merely through water motors, the ideal place to put the motor, of course, would be the sea level; then we should get our maximum potential, if we had our mains big enough, we should get our full potential at the water wheel, we should get the full head, so to speak.

An ideal electric power system should be built on exactly the same principles. We have in the city of Boston in the West End Railroad system, three separate powerhouses, one at East Cambridge, one on Albany Street and one in Allston, not very far from Cambridge. These powerhouses are the reservoirs. We would, if we chose, go back of this reservoir to the sun's heat again and think of the coal being formed, the trees growing centuries ago in the tropical regions, storing up this immense amount of potential energy, this

ıal then placed under the boilers and producing steam, that steam
ansformed into mechanical energy in the steam engine and the
eam engine giving up its power to the dynamo, which sends out in
e form of electricity 95 per cent of the power given to it. Now, in
ır electrical plant we really get our highest potential at what we call
e positive pole of the dynamo. The current of electricity flows out
om the positive pole of the generators. These generators are cou-
ed together, say in multiple, that is, all the positive poles together.
s two or three steam fire engines may all throw their water into
ıe line of hose, so all the generators throw their energy from the
ısitive side of the dynamo on to the feed wires. These feed wires
diate to all parts of the system. From the East Cambridge power-
ıuse, for instance, they extend to Arlington, all parts of Cambridge,
me parts of Boston, to Everett, Charlestown and Somerville. Now,
en, we have these immense main feeders radiating out from the
ation, upon which the current flows. They should be of sufficient
pacity to carry the current without a fall of pressure, the same as
ith our water mains, when we draw all that the generators are cap-
ıle of developing with safety at the end of our lines.

Now, if I may refer to a water works system again, every particle
current which leaves these feeders and goes through the cars must
turn to the negative pole of the dynamo, as in the water works sys-
m every particle of water which runs out from the faucets must find
; way back to the sea level. In the same way the electric current
mes back. We lose in our water works system a large amount of
r power in consequence of distributing the water at a higher level
an the sea level, in the electric system this should not be necessary.
ıe current goes through the feeders to the trolley wires, through the
olley down the pole to the car, through a concealed wire to the
otor under the car. This motor should consume all the energy, and
ıen the current leaves and goes into the rail it should have an easy
th upon which it can return, so easy that there will be no loss of
essure noticeable on the return. When electric cars were first put
operation in Cambridge they depended upon mother earth, the
ıter pipes, the gas pipes, and anything over which the current could
ıw, to convey it to the station or act as a sewer. No thought was
ven to the loss which would result to the company from doing this,
say nothing about the effect upon our pipes. I can perhaps illus-
ıte this loss by saying that three months ago in parts of Cambridge
e loss of pressure due to the power which was required to force this
rrent back over this uncertain path was 20 per cent. Now, when I
l you that the central stations of the West End Railroad Company

have a maximum capacity of 12,000 horsepower, which would give sufficient current for 24,000 arc lamps the same as are used in our streets, or 120,000 incandescent lamps, such as we have in this building, you get an idea of the power which is being sent out. When you think of that current returning, as it has been obliged to return, you can see that there must be an immense amount transmitted over our pipes.

The effect of this was called to my attention by the superintendent of the Cambridge Water Works, who is ever vigilant in these directions, and a series of tests were made to ascertain the quantity, and a little reasoning was done to determine the consequences. Electric currents have nearly the same laws as hydraulics. You take a 2-inch pipe and a 4-inch pipe, not counting in friction, the 4-inch pipe will carry four times as much water as the 2-inch, the amount varying directly as the square of the diameters. The current of electricity which will flow through two wires side by side is in the same proportion, the larger the wire, the larger the current, varying as the squares of the diameters of the wires. We use a little different form from what you do, and instead of speaking of diameters we speak of wires now as of so many circular mills. This gives us immediately the idea of the amount of current which will pass over those wires. It is simply the diameter in thousandths of an inch squared.

Now, when we come to the word resistance, I want you to bear in mind this: The resistance is the same as it is in a water pipe, in one sense; you get small resistance through a large pipe, and the smaller the resistance the more water will flow. And the same rule holds with wire: the smaller the resistance the more electricity will flow through it. If several paths are open we say the current divides inversely as the resistance. If the frictional effect or resistance of a wire is small, large amounts will flow. If we have two water pipes side by side running from the same reservoir, and we are drafting at the same point, if the pipes are of the same frictional effect, we shall have the same current of water flowing through the two pipes. Now, if we have two wires side by side attached to the same machine, the current will divide and will flow through those wires inversely according to the resistance. The larger the wire, the less the resistance and the more the flowage, provided they are of the same metal.

When the railroad company put in their power plant, they ran large numbers of feeders, as we call them, and one wire between the rails and attached the two rails to this return wire, so that the current, as I said before, will go to the car through the motor to the wheels, to the rails, and get along as best it can back to the station.

This became very soon an uncertain path, as it was found that electrolytic action took place upon this wire and it disappeared in places. They thought at first that it was due to something in the soil, but it was very soon traced to the same enemy which you have to contend with, that is, electrolytic action. I remember the practical experience we had with these dead rails, as we call them. When this wire was eaten off and a car came on to that section, if by any chance you placed one foot upon the rail and another upon the ground near it, shocks could be obtained. That happened simply in this way. The current must get back to the station, and it would take to the rail, which was not well grounded, would go up one leg of the man who stood on the rail and down the other to the earth, especially if the earth was a little moist, dividing again inversely according to the resistance.

The effect was so great that the West End Railroad Company made a complete change and reversed the conditions. It would be as if you started with your water works system by pumping the water from the sea into the sewers, forcing it up out of the sewer pipes and back through the faucets and through the mains to the reservoir. That is, they attached the other pole to the earth to remedy this difficulty, and instead of sending the current out over the feeders they commenced about a year and a half ago to force it out through the ground, have it go up through the cars and back through the feeders. When I heard of this I immediately concluded we should have trouble from it, and that is why I told my friend Nevons so decidedly I had no doubt it would have an effect: and now I will state some of the effects that have been noticed in Cambridge.

Mr. Nevons and I went to the different places where we had traced these difficulties, or where they had been called to our attention rather, and found that lead pipes had disappeared in a short space of time, some even in six or eight weeks. Iron pipes had been tried with the same result, also galvanized iron; brass pipe had been put in and deterioration was noticed at once. Rustless iron was tried, and it did rust decidedly. (Laughter.) Well, it was not the work of any mysterious agent, but was the result of what almost all of you have seen in school experiments, that is, the decomposition of water. The current left the West End powerhouse at East Cambridge, it flowed through the ground, and of course, divided according to the resistance, and took to whatever conductor came in its way. It took to the rails, the water pipes and gas pipes. Now, we get no action except at what we call the positive pole. That is where the current is flowing out of the pipes, where it takes to the pipe there is no action. The current flowed along on the pipes, and in this particular case, it got down on to Bridge Street, which is near Charles River, and flowed along our supply pipes on the wharves and here it had to get across the river to propel the cars in Boston. Where it left those pipes action took place.

Well, the remedy, the quick remedy for that, of course, was very apparent, that is, to reverse the current. So the officials of the West End Railroad company were invited to a conference with the Water Board and myself, and I am pleased to say the company were willing and anxious to do anything in their power to obviate this difficulty. A certain amount of credit belongs to them for that, although, of course, they had a reason for wanting to do it themselves. They were losing anywhere from 5 to 20 per cent of their power in this return; and when you reckon the loss on 12,000 horsepower it is quite an item, if they could save 5 per cent of that by the investment of a large amount of money it was very desirable for them to do it. They were consequently perfectly willing to take hold of this matter. It was suggested at that time that a reversal of the current might be a good thing. Now, I can illustrate to you in a moment why that would have an effect. The current was reversed, and now takes to our water pipes in just the same places that it left them before. As I told you before, there is no action at the point of contact, where it goes into the pipe; it is only where it leaves it. Therefore you would expect a very rapid deterioration where it left the pipes near the powerhouse to go in to the machines there; of course we had to fix the pipes so the current would not leave them through the earth. The leaving through the earth would cause this effect. A difference in potential of 2 volts—our system of pressure; you call it pounds—in a current flowing from one piece of metal to another through moisture causes the decomposition of water, and water forms into the two gases, oxygen and hydrogen, at this place. Now, we speak of the oxidation of an iron pipe due to the attacking of the pipe by this gas. If it were pure oxygen there you can see we should have a very rapid attacking of that pipe. Then, we must find some means by which we can get the current off the pipe without having it go from the pipe to the earth, and we do it by soldering very heavy copper wires to the pipes in various places and carrying these copper wires into the powerhouse and attaching them to the negative poles of the machines, so the current has an easy path over which to leave the pipe. Of course the result is we get no electrolytic action because we don't have the current leaving the pipe through the earth connection, but through a solid metal connection.

Observations were made by several of the water works employees unintentionally. Some of the other gentlemen present could tell you about those, perhaps, better than I. Such an immense amount of current was flowing over the pipes that upon attempting to make a joint by putting oakum around the pipe, it was found that the electric arc was often sufficient to set fire to the oakum, frightening the men considerably, I imagine. This of course would not necessarily indicate a very high potential, but proved the presence of a large quantity of current in the earth. Tests were made in different parts of the city by means of instruments adapted for the purpose, and we found between North Cambridge, Harvard Square, Central Square and East Cambridge a fall of potential all the way from 25 to 45 volts. Now, you can reckon the percentage as well as I. There should be no fall of potential, but there was a loss, as I said, of from 25 to 45 volts, from 500 volts which is the maximum pressure, making more loss than can be allowed with economy. When we attached to the negative pole of the machine and made our tests from Harvard Square, we found a loss of 100 volts, or 20 per cent. of the pressure. You can now see, as I said before, why the company was very ready to take hold of this matter.

How are we to remedy the difficulty? I know of no way by which we can use the single trolley wire system and overcome this difficulty without putting up an immense amount of overhead returns, through which the resistance will be reduced to almost nothing. How far the company will be willing to go in this I cannot say. Their spirit has been so admirable in the past I have no right to suppose but what they are willing to carry it to that extent. Certainly the city will require it carried to such an extent that the pipes will be in perfect safety. The maximum amount of current which can be allowed to go over them I am unable to tell you at present, but a series of experiments are being conducted now at my house to determine this. I have some pipes buried in the earth, the current flowing over them, and I am watching carefully the deterioration daily. I am in hopes to make a report soon to the Water Board upon the maximum amount which can be allowed to flow upon iron pipes from which we will have no effect.

By doing what we did do, reversing the current and attaching our water pipes to the negative pole of the dynamo, we hurt one of our old friends seriously, that is, the Gas Company. You see the effect. The current will flow on the water pipes, and it has an easy chance to leave them through their connection with the negative pole of the dynamo. Now it flows along on a gas pipe and as soon as it can it will leave the gas pipe to take to the water pipe. I felt it my duty to make this clear to the president of the Gas Company, and called his attention to it, saying that something ought to be done to protect him, and a conference was had between the railroad people and the Gas Company, and I was invited to be present. At that time we made an arrangement with the company which will help it somewhat in that direction, and will help us as well as them. We propose now to connect the gas pipes and the water pipes together in all parts of the city. It will be done in buildings. A man from the West End company has been appointed who goes as a gas man to the different stores and factories, and in those places he will solder a wire to the gas pipe and also to the water pipe. This can do no injury to either, but will decidedly help both companies.

You will be a little interested, perhaps, to know of one or two experiments which we have tried in East Cambridge when investigating this subject. Mr. Nevons will be perfectly familiar with the new engine house at East Cambridge. It is not yet occupied. There is an old supply which comes in from one street that connected with the old house, and a new supply comes in from Otis Street, I believe. The mains are connected together at the corner of Third and Otis Street, and this engine house is on the corner. Now there is sufficient difference in potential between those two pipes so that if they are connected together by a medium sized copper wire, about a No. 18, it will heat the wire so hot you can't bear your hand upon it. There is sufficient power to run a good sized motor, and I suggested to the engineer that he put a motor in there and run a planing mill and a few other little industries to help out that section of the city. It is a matter of fact that if we could save all this energy which is being thrown away, we could run a large factory. In fact, if we run a copper wire from East Cambridge to Harvard Square I think at times there would be no difficulty in running the whole University Press by this wasted power.

It was a little surprise to me the way they attempted at first to return the current. Iron carries a current of electricity not as readily as copper; it has seven times the resistance. Now, there are girder rails, that have, we will say, 10 square inches, some of them have as high as 14 square inches sectional area. That would have a carrying capacity equal to a piece of copper 2 inches square. And yet these rails are bonded by a No. 4 copper wire, a wire smaller than a lead pencil. It seems quite ridiculous that they should ask this little bit of fine copper wire to carry as much current as a big rail, where they could have a piece of copper wire, as I said before, for these big rails, of at least two square inches sectional area.

There is another remedy also which we hope to carry out early in the spring, and that is to abolish completely this return wire between the rails, by cutting it into sections of about 400 feet, and connect each of these sections with the return wires. Most of the current will then return by these copper wires. Of course, some of it, as I said before, will flow over the water pipes; that cannot be helped as long as one side of the machine is connected with the earth.

Another remedy which is to be adopted, is a special line of feeders attached only to the water pipes; that is, a feeder will be run from the central powerhouse to the different parts of the city, which will not be connected with the machines at all, but will be connected with the water pipes at the central powerhouse and with the pipes in all sections of the city. This will also materially reduce the electrolytic action.

I have occupied more time already than I ought, but if any member of the Association desires to ask any questions I should be pleased to answer them.

The President. Gentlemen, this subject is open for discussion. I understand that there are two classes of persons, those who do not claim to know anything about this subject, and those who know a great deal more than they care to tell. That being the case, I do not dare to call upon anybody, but I should be glad to hear from any one, and Mr. Morse is ready to answer any questions.

Mr. Hazen. I would like to ask if the destruction of the pipes is entirely from the outside, or whether it is from the inside as well?

Mr. Morse. It is entirely from the outside, where the current leaves the pipe. We should have almost the same effect if there was no water in it. Where the current leaves the pipe it makes little pit holes in it as big as the end of your finger or thumb, a little crevice which will work clear through the pipes.

Mr. Hazen. Is the ferric oxide left there?

Mr. Morse. You would be surprised to see how much is carried away, and just what becomes of it I haven't been able to determine yet.

Mr. Holden. Does it affect one kind of pipe more than another?

Mr. Morse. Any kind of metal pipe would be affected. A remedy has been tried that I think will be successful in some sections, that is, the placing of the pipe in cracked stone. I think this has a decided effect. And, also, the placing of the pipe in cement, where the supplies go through muddy places, would be desirable.

Mr. Holden. Wouldn't a cement covering answer?

Mr. Morse. Yes, sir. But let me explain that we should get the flow of the current through a cement lined pipe, and if the supplies were not covered we should get the action on the supplies.

Mr. Tidd. I should like to ask if those spots you speak of are rust spots or holes apparently drilled into the pipe?

Mr. Morse. I think it is probably due in iron pipes to a very rapid oxidation of the pipe. It is quite difficult to make a deposit of iron, although it has been done repeatedly and is being done in some instances commercially. The effect is, however, I think, undoubtedly rapid rusting due to the formation of oxygen and hydrogen at the positive pole.

Mr. Tidd. I asked the question because in my experience in dry docks I have noticed that almost every steamer that comes into a dry dock has on the back side of the propeller, I mean the side towards the ship, pit-holes drilled into the propeller, sometimes half an inch in diameter and oftentimes as big as your hand, and drilled sometimes completely through the blade, but always starting from the back side. I asked the question because I have wondered whether there was any electrical action between the propeller and the water in friction. I have noticed that in every iron propeller I ever saw taken from a steamer, which had been in use one or two years; they always have these holes on the back side of the blade, and I didn't know but it might be something of that sort.

Mr. Morse. I am not able at present to account for that.

Mr. Coggeshall. I think perhaps some of us would be interested to know how much damage this has caused in Cambridge. I don't think it is generally known how serious a matter it is.

Mr. Morse. We would give a good deal if we knew. We simply know there has been damage, and of course a large amount of injury has not been located yet. We have discovered some of it, but we do not know how soon dozens of pipes may give out which have not yet been quite destroyed.

Mr. Gardner. Do I understand that the return wire between the ils has suffered this deterioration so it has been eaten ALL away?

Mr. Morse. Yes. I have seen that in several instances. Three ars ago complaints came to me that in a certain section of the city a horse stepped on a rail he would be knocked down. I investi- ated, and found that the wire was reduced to almost nothing, leav- g what we call a dead rail. You can see the effect at once. If a ır came in on that section, the current had to get back through the round, and it would go up through a horse's foreward legs, pass rough his body and down through his hind feet, and the result was severe shock.

Mr. Gardner. Was this a small wire?

Mr. Morse. About as large as a lead pencil.

Mr. Gardner. Did this deterioration in the wire occur in spots was it general?

Mr. Morse. I don't know how general. I know that in some ctions of the city they have been forced to make this return a cov- ed wire, almost insulating it, so they wouldn't get this effect. It ried in different soils.

Mr. Gardner. The reason I asked the question was because I ondered whether it was not possible that there was something in e soil that facilitated that action.

Mr. Morse. I think there is no doubt about it: there is a very eat difference in different soils.

Mr. Gardner. If that wire had been larger do you think the ac- on would have been the same, or was it due to the incapacity of the ire to conduct the current? In other words, had the wire been large ough to conduct the current readily would there have been this dis- tegration?

Mr. Morse. No, I think there would not. If the current could w back over the rail and wire very easily, much easier than it could ave it and take to the water pipes, the amount of the electrical ac- on would be so small it would have been years before we discov- ed it. Several months ago we were unable to locate grounds on r fire alarm system, and I wrote to the West End company com- aining of the size of their return wires, and last April they com- enced running a return wire just to overcome that difficulty.

Mr. Gardner. Wouldn't the remedy be to have a very large return?

Mr. Morse. Yes, that is it exactly, to have the return so large that there can be almost no resistance to it. The question which we are considering now is how much current we can allow with safety on our water pipes. It is not possible under the present system to make it so that there will be absolutely NO flow, and the question is how much we can allow with safety.

Prof. Drown. I would like to ask Mr. Morse if it were possible to cover the pipes completely with a non-conducting coating heavily coated with asphalt, whether there would be any deterioration?

Mr. Morse. If the pipes could be insulated from the soil in which they are placed there would be no action.

THE STREET RAILWAYS OF ATLANTA, GEORGIA

(The Electrical World, October 27, 1894, Page 441)

The following matter was inadvertently omitted from the article in our last issue under the above caption, and refers, except the last paragraph, to the Collins Park & Belt Railway:

The operating expenses average between $35 and $40 per day, and are divided as follows:

Motormen and conductors	$12.00
Superintendent and management	3.33
Other Labor	12.33
Oil	1.00
Coal	7.00
Repairs	4.00

Motormen and conductors receive $1.50 per day, their average number of hours of work being 13. Trackmen and firemen get $1.00 per day each, armature winder $2.00 per day, car inspector $1.25 per day, chief engineer $2.25 per day, and night engineer $1.50 per day. The road does a good business in summer, but loses money in winter. At the present rate the road is earning about 6 per cent on $500.000. or one-fifth of its cost. The road will continue to be operated by the receiver, Mr. Darr, until the times improve and the road can be sold.

The total investment in street railways in Atlanta is between four and a half and five million dollars. The three roads average very nearly 8.000 car miles per day and carry over 23.000 passengers daily.

INDEX

Citations on Electrolytic Corrosion in Various Cities in United States and Abroad

(Beginning year of 1890)

Pages 68 to 184

Pages

1. Atlanta, Georgia 184
2. Athens, Greece 76-77-78-79
3. Boston, Massachusetts....81-82-83-84-85-86-105-113-124-132-133-134-142-148-149-172-173-174-175-176-177-178-179-180-181-182-183-184.
4. Brewer, Maine 133
5. Brooklyn, New York...105-106-107-108-109-110-111-112-113-114-115-116-117-124-125-126-127-134-148-162
6. Cambridge, Mass....89-105-113-124-125-128-134-172-173-174-175-176-177-178-179-180-181-182-183-184
7. Canada 149
8. Cincinnati, Ohio 118-130-170-171
9. Cleveland, Ohio 118-125-128-129
10. Columbus, Ohio 106-113-124
11. Editorials 71-73-74-75-79-80-81-104-105-117-118-122-134
12. Hamilton, Ontario 89-106-113-124
13. Indianapolis, Indiana 86-89-113-124
14. London, England 70-83-131
15. Los Angeles, California 106
16. Louisville, Kentucky 118-125-128-129
17. Madison, Wisconsin 135-145-154-159
18. Marseilles, France 105-117
19. Memphis, Tennessee 136-137-138-139-140-141

Pages
20. Milwaukee, Wisconsin....85-86-89-90-91-92-93-94-95-96-97-98-99-100-101-102-103-104-106-113-124-130-134-142-155-156-157-158-159-160-161-162-163
21. Minneapolis, Minnesota 161-162
22. Nashville, Tennessee 88
23. Newark, New Jersey 119-120-170
24. New Bedford, Massachusetts 170-171
25. Newburg, New York 129
26. New Brunswick, New Jersey 129
27. New York, New York 138-148
28. Omaha, Nebraska 120-121-122
29. Paris, France 86-87-88-89
30. Paterson, New Jersey 162
31. Peoria, Illinois 118-123-124-125
32. Petersburg, Virginia 148
33. Philadelphia, Pennsylvania 170-171
34. Pittsburgh, Pennsylvania 69
35. Poughkeepsie, New York 163-164-165-166-167-168
36. Providence, Rhode Island 69
37. Quincy, Illinois 160
38. Saginaw, Michigan 72-76-78-79-106
39. Salem, Massachusetts 80
40. San Francisco, California 129-132
41. Sault Ste. Marie, Michigan 106
42. St. Joseph, Missouri 125
43. St. Louis, Missouri 118-119
44. Southampton, England 122
45. Toronto, Canada 137
46. Trenton, New Jersey 105
47. Washington, District of Columbia 83-170-171
48. Wilmington, Delaware 122-123-160

Announcement by E. E. Brownell 68
Peter Milne's Report at Milwaukee, Wis., Sept. 5, 1893.....89 to 10
Brooklyn, N. Y., Report of Board of Commissioners, 1893..107 to 11
Reference page giving various reports on electrolysis............13
American Water Works Association Report for 1894......137 to 163
Poughkeepsie, New York, Report for 1894 ....163 to 168
New England Water Works Ass'n Report for 1891-1892..172 to 18